

# State of the Art of Cost and Benefit Models for Digital Curation

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## Abstract

*This paper presents the results of an evaluation carried out by the EU 4C project to assess how well current digital curation cost and benefit models meet a range of stakeholders' needs. This work aims to elicit a means of modelling that enables comparing financial information across organisations, to support decision-making and for selecting the most efficient processes – all of which are critical for ensuring sustainability of digital curation investment. The evaluation revealed that the most prominent challenges are associated with the models' usability, their inability to model quality and benefits of curation, and the lack of a clear terminology and conceptual description of costs and benefits. The paper provides recommendations on how these gaps in cost and benefit modelling can be bridged.*

## Introduction

Sustainability is a key issue for a wide range of private and public organizations responsible for managing digital information assets such as business records, research data, cultural heritage collections, personal archives and other assets that represent value to the organizations and others [1]. To ensure timely funding, the organizations need to understand the economic lifecycle that they operate in and the costs and benefits that the assets incur or engender. Likewise, suppliers of asset management systems and services need to have detailed knowledge on what management activities are involved, how much they cost and what the cost drivers are. They also need to understand how the systems and services generate value for customers. This knowledge and understanding of costs and benefits supports the streamlining of businesses, increases in cost effectiveness and improves measurements of performance.

Stakeholders depend on the availability of sound financial information for accounting and budgeting to underpin this understanding. They must know the factual costs, for example records of the capital and labor costs required to develop and operate a specific system. But to understand the implications of the costs they must also have contextual information that describes the underlying assumptions about what is being priced, for example the specifications of the quality of a system (parameters such as how rigorous is the applied quality control, how well does it support ingest of different types of metadata and so on) and indications of the value that the system represents to different stakeholders. On the one hand this financial information allows financial transactions to be recorded and analyzed for internal management purposes (and possibly for legal purposes as well). On the other hand it can also provide a basis for comparing solutions and thus support decision-making.

Costing digital asset management—digital asset management is also known as digital curation—is not a trivial task for a number

of reasons, not the least of which we do not have a common understanding of activities included in digital curation. What's more, is that there are many interrelated activities involved in curation and these can be implemented in many different ways and they can be set up to meet different quality requirements. This complexity makes it hard to specify the activities in a precise and clear-cut way. Also, cost models require detailed information for their calculations and often that information is intertwined with that of other cost centres. Indeed, there are no standardized ways of breaking down and accounting for the cost of curation activities. On top of this, digital curation activities depend heavily on constantly evolving technologies, which in turn leads to repeated changes in systems and procedures, and thus also in the costs. Assessment of benefits of digital curation is even less explored.

Assessing the costs, benefits of undertaking digital curation and risks of not undertaking curation activity are not a new challenges per se, but coupled with the rapid growth in the amount and complexity of information assets, budgets for curation are increasingly under pressure and this has emphasized the need for reliable and comparable financial information to know where efficiencies can be achieved.

This is where cost and benefit models come into play. Over the last decade several models have been developed to help organizations assess the costs and benefits of digital curation. An overview of models and bibliographies can be found at the Open Planets Foundation website [2], in a blog post on the Signal [3] and in a deliverable report by the 4C project [4].

It is notable that institutions have seemed to find it easier to develop new cost benefit models as opposed to modifying and then reusing the existing ones. This has resulted in a relatively large number of different models. There are however similarities, and of particular interest is the connection to the Reference Model for an Open Archival Information Systems (OAIS) [5] that forms the basis of most existing models relevant to digital curation. In spite all the effort being put into research in the economics of digital curation there is still no consensus on the optimum way to model it. Today's trends are towards developing a unified theory of how to model the costs and benefits of digital curation, and to make models more standardized. Alignment of methodologies will help facilitate comparison of alternative scenarios and selection of best practices to ultimately gain efficiencies in digital curation [6].

The work we describe in this paper springs from the EU funded 4C project "Collaboration to Clarify the Cost of Curation" (2013-2015). One of the core goals of the 4C project, which we describe in this paper, is to evaluate how well existing cost and benefit models meet users' needs for assessing and comparing financial information, and to highlight possible improvements of current and future models. All details of this work are available in a 4C deliverable report [7].

The work presented in this report benefits from the recent work done by the APARSEN project, which also analyzed cost models in digital curation [8-9]. However, the APARSEN project focuses on benchmarking cost models' activity structure against the ISO 16363 standard "Audit and Certification of Trustworthy Digital Repositories" while 4C aims to evaluate models against stakeholders' needs, and thus takes on a wider perspective aiming to evaluate not only how the models breakdown costs by activity but also by other dimensions and how they model cost drivers as well as various aspects of the models' functionalities, usability, and the like.

In the absence of a standardized definition of digital curation the 4C project has delimited and defined it on the basis of the OAIS Reference Model. This standard includes a functional model that describes a conceptual repository for long-term preservation of information – and three roles that interact with the repository, namely Manager, Producer and Consumer. In this context we term all activities related to the role of Producer as Pre-Repository activities, and those related to Consumer as Post-Repository activities.

We define a cost model as a representation that describes how resources – direct capital and labor costs, as well as indirect costs (overhead) – required for accomplishing digital curation activities relate to costs. Indirect costs denotes costs that incur by the usage of shared resources – such as general management and administration, common facilities and systems – where it has not been feasible to distribute the costs on specific activities. Cost models can further be characterized by their cost structure – the way they define and breakdown activities and resources, and by the way they define and handle the cost variables that influence the costs. These factors include, for example the quantity and quality of the information assets an organization needs to curate, the quality of the applied curation services, and the retention time (short, medium or long-term). They also cover possible economic adjustments, such as inflation/deflation, depreciation/amortization, and interest (discount rates). Finally, costs can be described according to time as one-time costs or recurring costs. A benefit model is in this context loosely defined as a representation that describes the benefits (financial and non-financial) and value of digital curation.

## Problem

There is a lack of consensus within the digital archiving and curation community on how to define, structure and model cost and benefits of digital information assets. This deficiency impedes exchange and comparison of information, which could otherwise help stakeholders establish a common knowledge base of financial information from which they could mutually learn about the most efficient curation processes to support the sustainability of information assets. As a first step to elucidate this problem, this paper provides an evaluation of the current state of the art of cost and benefit modeling in the field of digital curation.

The main focus of the work is on cost modeling in the field of digital curation. However, we fully acknowledge that costs are inextricably interwoven with the benefits and value that they bring, and therefore we also included benefit models in the evaluation.

The evaluation describes the individual models strengths and weaknesses and seeks to identify best practice—effective ways of

modeling costs and benefits that more users can apply, and which can also be used as a benchmark for improving modeling methods further.

## Methods

To facilitate the model evaluation we first defined a basic terminology and described the components of cost and benefit models in the field of digital curation. Based on a literature review we then identified existing models and described their core properties in a structured way to enable easy comparison, so that potential users can get a quick overview of what models they may want to use. A list of the names, acronyms and owners of the ten cost models we included in the study is provided below. For further references to the models see [7.]

1. Testbed Cost Model for Digital Preservation (T-CMDP), National Archives of the Netherlands, NL
2. NASA Cost Estimation Tool (NASA-CET), National Aeronautics & Space Administration, US
3. LIFE3 Costing Model (LIFE3), University College London and The British Library, UK
4. Keeping Research Data Safe (KRDS), Charles Beagrie Limited, UK
5. Cost Model for Digital Archiving (CMDA), Data Archiving and Networked Services, NL
6. Cost Model for Digital Preservation (CMDP), Danish National Archives and The Royal Library, DK
7. DP4lib Cost Model (DP4lib), German National Library, DE
8. PrestoPRIME Cost Model for Digital Storage (PP-CMDS), The PrestoPRIME project
9. Total Cost of Preservation (CDL-TCP), California Digital Library, US
10. Economic Model of Long-Term Storage (EMLTS), David Rosenthal, US

Then we investigated stakeholders' needs for financial information through a web consultation to elicit their priorities and the implications of these on the required capabilities of cost and benefit models. The consultation consisted of a set of general questions about the stakeholders' organization, information assets and motivation for curation and a set of more specific questions relating to stakeholders' needs for financial information and their current cost modeling practices. The questions had pre-defined answers to choose from, either single or multiple choice, and most also allowed for providing comments. The consultation reached contact with 176 stakeholders, of whom 46% completed the first part and 28% the full survey. We surveyed users and potential users of cost and benefit models about the content they need to curate and current practices, their motivations for curation, and what they need the financial information for and in which form they would like this information.

Based on this analysis we transformed the needs into requirements for cost and benefit models formulated as Boolean questions (Yes/No). This formulation was leveraged through engagement with model developers from within the 4C project team. The 79 different requirements we derived were assembled as a schema and grouped according to four main characteristics of cost and benefit models reflecting the type of model, the cost

structure (activity and resource), the cost variables and the usability of the models.

Next we performed an evaluation of each of the models against the identified requirements to identify gaps in the capabilities and to assess the overall usability of the models, as well as to highlight good practices for models users and developers. Due to the fact that the models differ considerably in scope and design, we did not aim to rate the models' effectiveness, but rather to enable a comparison of specific characteristics of the costs models' functionality. The models capabilities were assessed through the structured model descriptions, available model documentation and through testing the tools themselves. Gaps were defined as shortcoming between users' needs as identified in our survey and the capabilities of the models based on our evaluation. We included gaps in individual models and also identified gaps in the collective mass of models. For the purpose of this study, if less than half of the evaluated models did not handle a requirement this was considered to be a gap.

## Results

### Model descriptions

We have provided a structured description of each of the ten models, stating among other things which types of information assets each of the models can handle, which curation activities the models cover, which cost parameters they include and which cost variables they model, in a schema. These descriptions are available on the 4C web site ([www.4cproject.eu](http://www.4cproject.eu)) and in the full report [7]. Table 1 shows an overview of the curation activities (pre-repository, repository, post-repository) and types of information assets (generic, specific (office documents (o), research data (r), audiovisual materials (a/v) that the models cover. Repository activities include: Ingest (IN), Data Management (DM), Archival Storage (AS), Access (AC), Preservation Planning (PP), Administration (AD), and Common Services (CS).

**Table 2: Overview of the curation activities and the types of assets that the models can handle.**

Curation activities	Generic assets	Specific assets
Pre-repository, Repository		KRDS (r) LIFE3 (o)
Repository	CDL-TCP	DP4lib (o)
Repository, excl. AC		T-CMDP (o) CMDA (r)
Repository, excl. PP		NASA-CET (r)
Repository, excl. DM, AC		CMDP (o)
Repository, excl. IN, DM, PP		PP-CMDS (a/v)
Repository, excl. IN, DM, AC, PP	EMLTS	

### Stakeholders' needs analysis

The stakeholders who took part in the consultation represented various types of organizations: 37% memory institutions or other content holders, 20% Commerce (including digital preservation vendors, publishers, SME, data intensive

industry), 13% Universities, 9% Government agencies, 9% Big data science, and 12% were categorized as "Other". Regarding their motivation for curation the stakeholders indicated that it was driven by the need to ensure the availability of public goods, to meet legal requirements and/or business requirements. 70% of the organizations indicated that public funding is the main source of their curation activities, and 61% that digital curation is their core activity. Approximately two out of three organizations perform the curation activities in-house, while the rest outsource all or part of these activities. The consultation also showed that organizations need to account for different types of information assets, retained for different time periods from short over medium to long term, and that they need to account for various quantities and qualities of assets. It also showed that different target audiences, including accountants, directors and repository managers, i.e. with different levels of technical knowledge about digital curation are responsible for accounting and budgeting.

When the stakeholders were asked about their current accounting practices the majority indicated that they do not break down costs incurred by curation (see Figure 2).

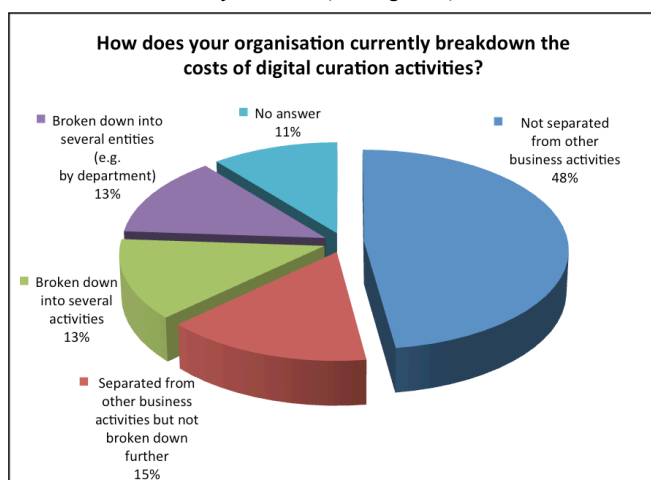


Figure 2. Shows how the organizations currently breakdown cost of curation.

When asked to select the three most important drivers for selecting a cost model the most popular statements selected by the stakeholders were "To inform decision makers", followed by "To find out the cost of preserving assets" and "Ensure efficient use of resources". Likewise, the stakeholders were asked to indicate which statements best matched their reasons for selecting and using a cost model and here the three most popular selections were "Is the model easy to use and adaptable", followed by "Model has been validated by a similar organization in your sector" and "The scope of the model".

However, the consultation also showed that only 20% of the organizations use or have tried to use a cost model – the majority determine costs based on experience. Those who had tried to use a cost model stated several challenges using the current models including that the models are imprecise, difficult to adapt and do not map well to activities in their organization, lack clear definitions of activities, and that they are generally difficult to use and miss guidance. Consequently, when asked how the models could be improved the stakeholders recommended to improve the

models reliability and accuracy, to provide better definition and more detailed breakdown of activities, clearer differentiation between cost types such as fixed and variable costs, better ability to model complex objects, application of economic adjustments, refinement of cost drivers, and development of software to facilitate modelling.

In summary the analysis of stakeholders' needs for financial information showed that, to be useful, cost and benefit models should be reliable, well documented and accommodate for a wide range of information assets and organizations (use-cases). In addition, the models should support accounting, but more importantly they should support budgeting and thus strategic planning activities. Stakeholders also emphasized that the models should support assessment of benefits and value of digital curation and thus allow for a more complete economic analysis. Last but not least the stakeholders requested easy to use models and tools.

Some of the stakeholders' needs expressed in the consultation could be transformed directly into requirements for the models' capabilities and used in the following model evaluation and gap analysis others needed some interpretation.

### **Model capability evaluation**

The detailed results on all the 79 different requirements we evaluated for each of the ten models are available in the full report of this work [7]. Here we only present the most important gaps and findings for each of the four main characteristics evaluated.

The characteristic "Model Type" evaluated various aspects of the models including their ability to account for past cost and/or project future costs, and their ability to model benefits. We identified a gap in the models ability to assess benefits, which was a clear demand expressed in the stakeholder consultation. Only two of the cost models reviewed enable this. The KRDS Benefits Framework Tool identifies benefits and the KRDS Value-chain and Benefits Impact Tool helps identify potential measures or illustrations of the value and impact of those benefits. These two tools are meant to be used in conjunction with the KRDS activity based cost model. The CMDA includes a balanced scorecard approach to ensure that the mission of an organization and existing strategies are translated into strategic objectives that can be measured operationally.

In the characteristic "Cost Structure" we evaluated how the models structure cost data by activity and resource (direct capital and labor, and indirect costs) and at what level of detail. Stakeholders expressed the need for guidance on specification and definition of digital curation activities that incur cost, and in fact the majority of the models do provide useful checklists of activities to support this. However, even though most of the checklists are based on the OAIS functional model, there are significant differences in how the activities are outlined. Likewise, there are large differences in the way resources are structured. While models with well defined cost structures provide a sound basis for costing the lack of standardization impedes comparison of cost data.

In the category "Cost Variables" we analyzed the models' ability to cover variables, which have an impact on the costs with a focus on the quantity and quality relating to information assets and curation services. When compared with the stakeholders' needs we identified a lack of models that address certain aspect of the quality of the curation services, including the upload/download capacity of

repository systems, and more importantly a lack of models that allow users to specify the quality of repositories. The quality of a repository's system and processes influences costs. Certifications help to establish comparable procedures and quality measurements. Cost models undertaking such certification initiatives may be a way to enable cost comparison across different repositories and systems. The CMDA defines as prerequisite that an organization using this model has the philosophy of a trusted digital repository. However, it does not include compliance with a specific standard.

The characteristic "Functionality and usability" addressed among other things intended users of the models, documentation, learning curves, and availability of software to support the cost models. Most of the models are supported by good documentation, but there is a general need for guidance on which models to select for specific use cases as well as start up guides. All models, except KRDS and CMDA, are associated with software to support costing, ranging from spreadsheets to online tools, and most tools use algebraic formulas. However, we found that there is a lack of tools with Graphical User Interfaces. Also there is a gap in the models' ability to be used by general managers who are not specialists in digital curation.

### **Discussion**

One of the most important gaps we identified is the general lack of usability of the models, a gap primarily linked to the guidance and support documentation associated with the models. Even though the support documentation is often very detailed, in most cases a simple introduction to the scope of the model that would allow the potential user to quickly find out if the model is appropriate were lacking. For this reason we have recommended to make the selection and use of the models easier by creating high-level overall user guides to the models using plain language and common descriptive elements detailing what the models and tools can provide, who should use them, and when they should be used. The summaries of the models we have provided through this study [7] represent a starting point for bridging this gap [7].

Another factor affecting the usability of models is the absence of simple graphical user-interfaces for the tools. From evaluating the models we found that applying pre-defined formulas, parameter and values, could greatly enhance the ease of use of the models and help provide guidance on good practices.

Most of the evaluated models require input from specialists in digital curation. However, the stakeholder consultation showed that in many cases those responsible for the accounting and budgeting were account managers and general managers. This implies a need for models that are easy to understand—not relying on in depth technical knowledge for instance—and well described using non-technical language. Thus, the models must facilitate communication between curation specialists and non-specialists and this emphasizes the importance of a clear documentation of models to make them easier to understand and use at the management level.

Users are inclined to prefer—to trust—models that are based on standards and validated within the community. The accuracy of models also plays an important role. It is however very difficult to evaluate the existing models' accuracy and precision. This is due to the diversity and complexity of the models and because empirical cost data is scarce. One of the clear complaints from

stakeholders about models is that they are complex to use. However, the required level of detail of the models is directly linked to the accuracy of the models and thus represents a trade-off. Again this challenge due to complexity can be met by good user-guidance and user-interfaces of the tools. Establishing open knowledge bases where the community can share cost data could be an effective way to refine the accuracy and precision of the models. Reliability is also related to the models' ability to provide clear and transparent definitions of curation costs.

The consultation showed that digital curation activities are often part of other business activities, which makes it difficult to extract and analyze the costs. A well understood cost structure would also facilitate outsourcing some or all activities and the estimation of these expenses. Nevertheless, there is no agreement within the community on how digital curation activities, cost elements and cost variables are termed and defined, and this is a major obstacle for sharing, comparing and understanding cost data and contextual information. The present work clearly shows that the lack of a universally accepted terminology and clarification of cost and benefit concepts is an important obstacle for reaching consensus on how to model these. Such framework could possibly be integrated into the 4C project's work to develop a Cost Concept Model (CCM) and Economic Sustainability Reference Model (ESRM) [10].

One of the most prominent challenges we encountered through the stakeholder consultation concerns the models' adaptability to other use-cases than the ones they were created for, which can also be tracked down to the lack of consensus on how to define, qualify and breakdown costs. The challenges model users will likely encounter when trying to transfer financial data between models was also confirmed in a recent APARSEN study [9].

As the consultation showed, stakeholders need to assess the costs and benefits of curating different types of content, in various amounts, various complexities and with different requirements for access and availability. They need the models to fit their purpose—address the required information assets and the right curation activities and resources, and at the right level of detail. The current models break down costs in different ways, in different activities and functions, in different cost elements (onetime/running; direct/indirect; capital/labor and so on) and apply different accounting periods. This is understandable given that most were devised in order to fulfill a particular need in particular organizations with established accounting procedures. However, this adherence to a specific cost breakdown is a barrier to the adoption of a model by organizations that need to handle other amounts and types of information assets and/or apply different curation services. Consequently, there is a need for a standard costs structure, yet flexible by nature.

For the purpose of streamlining any one organization and optimizing activities internally, there may not be a requirement for a common standardized breakdown structure. However, if we want to compare costs across organizations or for different services, to learn from each other's practices and identify the most efficient ways of handling digital curation, we need to define and break down costs in a more transparent and uniform way. Most models break down activities based on the OAIS functional entities, and this seems to be a sound way of describing the activities. However, the OAIS model does not cover all curation activities and it is an

abstract model that intentionally does not reflect actual implementations and practices. Thus the OAIS functional model cannot be directly used as basis for assessing costs since costs can only be assessed for concrete systems and procedures. Regarding the breakdown of cost in elements and use of general accounting principles there are no standardized ways of doing this within the digital curation community. The Transparent Approach to Costing (TRAC), which is applied in Higher Education in Britain, has been suggested as a methodology for recording resource cost data [10].

The requirement for a standardized way of recording costs is in tension with the fact that at the same time stakeholders also want the models to offer a high degree of flexibility and adaptability to local configurations. This Gordian knot suggests that there is a need to design a high-level cost and benefit framework that can represent most types of organizations and information assets, possibly along the lines of the OAIS standard as well as accounting and budgeting standards, and yet be adjustable to specific use cases. It is still an open question whether this is feasible due to the inherent complexity of such all-inclusive framework.

To facilitate comparisons of costs we also need more formalized ways of describing the quality of the priced curation activities and services. Regarding the quality of repositories the adoption of audit and certification practices could bridge this gap.

Comparing the costs, risks and benefits of different scenarios to support decision-making and funding requests is a considerable driver for managers, who form the largest potential user group for cost models. Only two of the models, CMDA and KRDS, include means of relating costs and benefits, the former using the Balance Score Card (BSC) methodology and the latter using checklists of benefits. Awareness of the benefits of curation is essential for organizations—whether they consume or supply curation services—in order for them to sustain their business cases. Whilst the cost of curation basically depends on the quantity and the required quality of the information assets—which, in principle, can be assessed objectively for a particular scenario—the benefits of the scenario depends on the stakeholder perspective—and as such the identification and assessment of benefits is subjective, and this should be reflected in the way that cost and benefit models are designed. To this end the 4C project has also engaged with stakeholders to elicit their priorities regarding various types of benefits, including among others risk, trustworthiness and sustainability, and these concepts and the results of the engagement are described in a deliverable report [11].

The evaluation of the cost and benefit models also led the team to develop some insights into what seems to be good practice for developers of models for the cost of digital curation. As in many other areas, the good practice for model developers is in general to keep it simple (for more details see [7]).

## Conclusion

In this paper we have described the work done to evaluate current cost and benefit models in the field of digital curation against stakeholders needs for financial information to reveal gaps in the capabilities of the models and point to ways in which cost and benefit models may be improved to increase their usability.

The stakeholder consultation showed that users' primary requirement is for models that are easy to use, reliable and fit for purpose. Overall, the quality of the models reviewed is high and

there are a number of excellent features in each that help specific user communities get a good grasp on their curation costs. But there is room for improvement to make these models more usable and valuable to a wider range of stakeholders. The most challenging of the gaps identified relate to the lack of intuitive and easy to use tool interfaces and simple userguides; the lack of validated models for use by target communities, an inability to adequately model the required use cases; and a lack of standardized definitions of curation to support comparison between alternate options. A last challenge, which is not directly an impediment for the use of the models, is that there is a significant lack of functionality that cater for the users' requirement that models that support both costs and benefits since most of the models are purely cost focused.

But further work is needed in this area. The 4C project will be working closely with a range of stakeholders in the coming months to better understand what users need and how cost information might best be shared and exchanged. In particular, there is a need for agreeing on a standardized yet flexible framework for assessing the costs and benefits of digital curation capable of meeting a much wider range of use-cases. Also a clearer definition of terms and concepts of cost and benefits of digital curation will provide for a better understanding of these complex relations and facilitate exchange of cost and benefit information and ultimately support the establishment of the most sustainable practices in digital curation.

## References

- [1] 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](http://brtf.sdsc.edu/biblio/BRTF_Final_Report.pdf)
- [2] Open Planets Foundation, Digital Preservation and Data Curation Costing and Cost Modelling, <http://wiki.opf-labs.org/display/CDP/Home>
- [3] The Signal – Digital Preservation, A Digital Asset Sustainability and Preservation Cost Bibliography, <http://blogs.loc.gov/digitalpreservation/2012/06/a-digital-asset-sustainability-and-preservation-cost-bibliography/>
- [4] M. Ferreira, and L. Farier, Baseline Study of Stakeholder & Stakeholder Initiatives, 4C D2.1 (2013), [http://www.4cproject.eu/component/docman/doc\\_download/8-d2-1-baseline-study-of-stakeholders-stakeholder-initiatives?Itemid=](http://www.4cproject.eu/component/docman/doc_download/8-d2-1-baseline-study-of-stakeholders-stakeholder-initiatives?Itemid=)
- [5] CCSDS (Consultative Committee for Space Data Systems), Reference Model for an Open Archival Information System (OAIS), CCSDS 650.0-M-2, Magenta Book, (2012), (ISO14721:2012), <http://public.ccsds.org/publications/archive/650x0m2.pdf>
- [6] Lungu et al. "Economic Alignment", in *Aligning National Approaches to Digital Preservation*, ed. N. McGovern (2012), 195-268, <http://educopia.org/publications/ANADP>
- [7] U. B. Kejser et al., Evaluation of Cost Models and Needs & Gaps Analysis, 4C D3.1 (2014), <http://4cproject.eu/community-resources/outputs-and-deliverables>.
- [8] K. Kaur et al., Report on testing of cost models and further analysis of cost parameters, APARSEN, D32.2, (2013) <http://www.alliancepermanentaccess.org/index.php/knowledge-base/member-resources/documents-and-downloads/?did=150>
- [9] K. Kaur et al., Report on cost parameters for digital repositories, APARSEN, D32.1, (2013), <http://www.alliancepermanentaccess.org/index.php/knowledge-base/member-resources/documents-and-downloads/?did=123>
- [10] N. Grindley and B. Lavoie, Draft Economic Sustainability Reference Model (2013), <http://4cproject.eu/community-resources/outputs-and-deliverables/ms9-draft-economic-sustainability-reference-model>
- [11] Beagrie, N., Chruszcz, J. and Lavoie, B., Keeping Research Data Safe. A Cost Model and Guidance for UK Universities, (HEFCE 2008), p. 13, <http://www.jisc.ac.uk/media/documents/publications/keepingresearchdatasafe0408.pdf>
- [12] 4C, D4.1—A prioritised assessment of the indirect economic determinants of digital curation, (2013), <http://www.4cproject.eu/community-resources/outputs-and-deliverables/d4-1-a-prioritised-assessment-of-the-indirect-economic-determinants-of-digital-curation>

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