OECD publishing

DIGITAL PLATFORMS FOR FACILITATING ACCESS TO RESEARCH INFRASTRUCTURES

OECD SCIENCE, TECHNOLOGY AND INNOVATION
POLICY PAPERS
December 2017 **No. 49**

OECD
BETTER POLICIES FOR BETTER LIVES

This paper was approved and declassified by the Committee for Scientific and Technological Policy (CSTP) on 24 October 2017 and prepared for publication by the OECD Secretariat.

Note to Delegations:

This document is also available on OLIS under the reference code:

DSTI/STP/GSF(2017)4/FINAL

Foreword

The OECD Global Science Forum (GSF) and the Science and Technology Policy Institute of Korea (STEPI) activity on digital platforms for facilitating access to research infrastructures (RIs) was part of the OECD-STEPI project on Open and Inclusive Collaboration in Science. It is also a contribution to a larger portfolio of work by the OECD Committee for Scientific and Technological Policy (CSTP) and GSF on digitalisation and open science.

This project is based on an analysis of eight case studies of initiatives that are using digital platforms to promote broader access to and more effective use of RIs. The main focus is on the development and maintenance of these digital RI platforms, which aggregate information (or meta-data) on a defined selection of RIs and provide a variety of associated services.

The report aims to be useful to policy makers and to project managers and administrators who are contemplating setting up, restructuring or extending similar digital RI platform initiatives. It should promote a broader understanding of how such initiatives are currently running and how they might be used to bring RIs and potential users together. The conclusions and suggestions in this report are not meant to be prescriptive. Nevertheless there are a number of common issues and lessons learned that are broadly applicable.

The literature analysis, survey and interviews for this study were carried out by Dai Qian from the OECD-GSF Secretariat (on secondment from MOST, People's Republic of China, hereafter "China") and Eunjung Shin (STEPI, Korea), with support from Ana Helman (European Science Foundation). The preliminary results were discussed at an international workshop on Open and Inclusive Science in Seoul on 29-30 June 2017 that was hosted by STEPI. The final report was drafted by Dai Qian, with input from Eunjung Shin and Kyungmo Sung and final editing by Carthage Smith.

This publication is a contribution to the OECD Going Digital project, which aims to provide policymakers with the tools they need to help their economies and societies prosper in an increasingly digital and data-driven world.

For more information, visit www.oecd.org/going-digital

#GoingDigital

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Abstract

Shared research infrastructures are playing an increasingly important role in most scientific fields and represent a significant proportion of the total public investment in science. Many of these infrastructures have the potential to be used outside of their traditional scientific domain and outside of the academic community but this potential if often not fully realised. A major challenge for potential users (and for policy-makers) is simply identifying what infrastructures are available under what conditions. This report includes an analysis of eight case studies of digital platforms that collate information and provide services to promote broader access to, and more effective use of, research infrastructures. Although there is considerable variety amongst the cases, a number of key issues are identified that can help guide policy-makers, funders, institutions and managers, who are interested in developing or contributing to such platforms.

Key words: science policy, research infrastructure, digital platform, meta-data, open access.

Executive summary

Improving the provision of, and access to, research infrastructures (RIs), which account for a substantial percentage of public investment in science, is an important policy challenge in most countries. Opening up access to infrastructures can make a significant contribution to Open Science. This requires addressing the needs not only of national research communities but also those of other users, both internationally and from sectors outside of academic research, most notably in industry. A first step in meeting these various needs is collecting, analysing and/or disseminating information on what research infrastructures exist, what they do and how they can be accessed. Digital platforms (meta-data catalogues and associated services) of RIs are an invaluable tool for ascending this first step.

There are a variety of digital RI platforms that have been developed, in a largely *ad hoc* and uncoordinated manner, over the past two decades and that are more or less used and more or less useful. Some of these started via digitalisation of existing paper records, whereas others began *de novo* with automated digital data collection and mobile apps in mind from the outset. They cover a range of domains that may be institutionally, geographically or scientifically determined and they have different mixes of sponsors, data providers and users. There is an important distinction between those platforms whose main mission is to provide comprehensive up to date information for analysis and planning and those whose function is more that of a service provider with a brokering role, although in practice many initiatives attempt to fulfil both functions to some extent.

This report is based on an in-depth analysis of eight case studies, representative of different types of digital RI platform from different countries. Information was collected on key aspects of the design and functioning of these eight platforms, using a questionnaire survey and follow-up interviews. This was then analysed in terms of the different phases of the life-cycle of a platform (conceptualisation through to evaluation) and key aspects of aims, design and functioning.

Despite the tremendous variety and limited sample size, there were a number of issues that consistently came to the fore and which need to be addressed at the policy and/or operational level in order to develop efficient, effective and sustainable digital RI platforms. These key issues are listed below and expanded on in more detail at the end of this report.

1. **Landscape analysis** - many RI databases and platforms already exist and before developing new ones a thorough analysis of the existing landscape should be performed.
2. **Platform objectives** need to be clearly defined at the outset in consultation with key stakeholders (data providers, users and sponsors).
3. **Do not underestimate data-related work**, including definitions and standards, data acquisition and engagement with providers, data maintenance and data expansion.
4. P**latform services** depend on a solid data foundation and must be designed to meet user needs.
5. **Both data and platform services are assets** and serious consideration should be given to how to create value from these assets. A well-defined business model,

including value propositions for different actors, can provide a foundation for future evaluation and long-term sustainability.

6. **Emerging digital tools** are opening up new possibilities for automation and efficiency gains as well as service provision. However, their development and adoption requires forward planning and investment.
7. **International co-operation** around definitions, standards and interoperability is necessary.

1. General background

1.1. Introduction

Research infrastructures (RIs) or shared facilities play a pivotal role in research and innovation and require considerable public investment. They include large experimental facilities, such as telescopes or synchrotrons, as well as biobanks, high performance computer centres and data archives. They can be located in a single site or distributed across multiple sites. Access to these facilities can be crucial for research in many domains and is thus of considerable policy interest. In this context, access can be broadly defined as "the legitimate and authorised physical, remote and virtual admission to, interactions with and use of RIs and to services offered by RIs to users, who include academia, business, industry and public services" (European Commission, 2016).

Promoting effective and efficient access to RIs for a wide base of users is considered important not only in supporting Open Science and in optimising public investment, but also to address global challenges, which demand international and cross-sector collaboration. A range of different actions are being taken at the national and international level to facilitate RI access by different users. For example, innovation vouchers are being used in several countries to promote access for a range of innovation actors (e.g. Australian Government, 2013) while in China a national initiative for opening key RIs to new users is under way (State Council of China, 2014). In order to be included in the European Strategy for Research Infrastructure roadmap, RIs must adopt an “open access” policy for basic research activities (ESFRI, 2011) and there is an increasing emphasis on RIs as catalysts for innovation.

In order to have better access to, and/or investment in, RIs, scientists, decision makers and other stakeholders need to know first of all what is available. Thus, digital platforms that aggregate information or meta-data on RIs and provide a variety of user services, from basic searches to on-line reservation, are an important instrument for promoting access (see Table 1).

As their names indicate, a large diversity is found in these examples, which range from national initiatives to international collaborative efforts, from focusing on specific areas of science to covering much wider categories, and from providing the best available data for policy makers to promoting academia-industry collaboration.

Table 1. Examples of digital platforms of RI data and information services

(* case studies for this project)

Name	Coverage
Austrian Public Database of Research Infrastructures*	Austria
Canada Foundation for Innovation Research Facilities Navigator *	Canada
Finnish Research Infrastructure Service*	Finland
Infect-ERA	International
Mapping the European Research Infrastructure (MERIL)*	International
Marine Research Infrastructure Database*	International
National Platform for Key Research Infrastructures and Facilities	China
Netherlands Organisation for Scientific Research Large-Scale Scientific Infrastructure	Netherlands
Q Reserve	Canada
Research Infrastructure Database for European Plate Observing System	International
Research Infrastructures of Russia	Russia
RIsources – Research Infrastructure Portal by DFG*	Germany
Royal Microscopical Society Facilities Database	United Kingdom
UK University Facilities and Equipment Open Data	United Kingdom
ZEUS* & e-Tube*	South Korea

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1.2. Definitions and methodology

A variety of digital platforms that aggregate different types of information on RIs can be found on-line. These may focus on disciplines or domains of science, individual institutions, countries or regions. In terms of access, there is a diversity of platforms facilitating physical or remote access to RIs and/or the data generated by these facilities. Amidst all this heterogeneity, the present study focussed on initiatives with the following characteristics:

- They are digital platforms – websites, portals and databases;
- They are openly accessible for all users;
- They facilitate the knowledge of, interaction with, admission to or use of, a range of different RIs by providing information, guidance and a variety of on-line services.

Eight initiatives (marked * in Table 1) were identified for inclusion on the basis of diversity in disciplinary and geographic coverage, aims, information provision and services. A brief description of the key characteristics of these initiatives is given in Annex 1 and more specific information is provided in Boxes 1-8 of the report. During the period March to May 2017, a questionnaire survey was circulated to collect baseline information and this was supplemented by in depth follow-up interviews with key individuals for each initiative. Typically the interviewee was the project manager or director of the initiative (see Annex 1). The main aim of the surveys and the interviews was to explore different stages of the initiatives' development and to try to understand the key challenges and lessons learned, especially in relation to engagement of stakeholders.

The interviews were structured following the four (life-cycle) phases of the initiatives:

- Conceptualisation (history, objectives, platform and data structure and design, engagement of different actors, funding);

- Implementation (platform building, data curation, stakeholder co-ordination, digital tools);
- Operation (performance, operational tasks, impact-monitoring, out-reach, user and RI feedback);
- Evaluation (assessment, challenges, sustainability)

The preliminary analysis of the survey and interview results was presented and discussed in a half-day session at an OECD-STEPI workshop on Open and Inclusive Science (Seoul, 29-30 June 2017). The final report presented here includes consideration of the workshop proceedings.

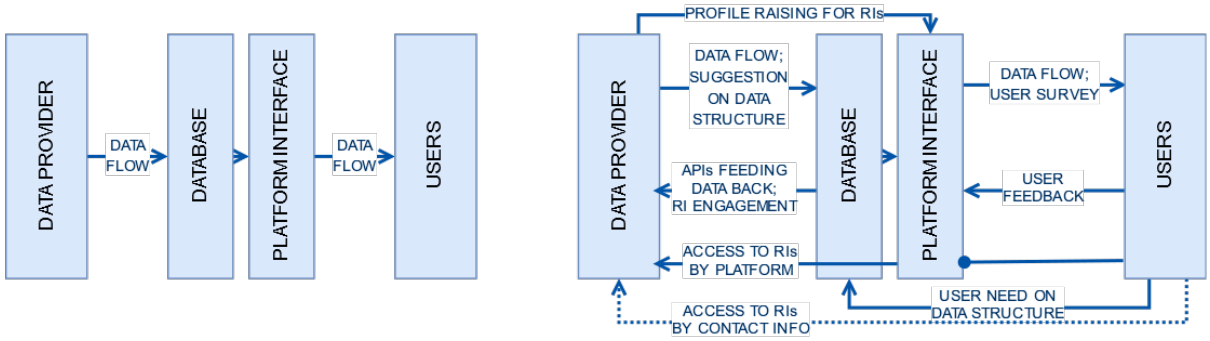
1.2.1. Main actors

The surveys and interviews revealed that three major groups of actors are always involved, to a greater or lesser extent, throughout the different life-cycle phases of a digital RI platform:

- The initiative itself, which usually has a structured database and an on-line platform interface, with dedicated staff hosted by a lead organisation;
- Data provider(s), who are usually the owners of the RIs, or bodies, such as academic associations or administrations with responsibility for specific research areas and that have part of the required data;
- Users, who are supposed to receive and make use of the available data, e.g. for accessing the RIs, mapping exercises or data analysis.

The relationship among the three groups of actors is important for understanding each initiative. A simple and straightforward relation would be a one-way flow of data from the data provider, to the database and platform, and on to the users. However, the surveys and interviews invariably revealed a more complex picture. For example, instead of just receiving data, users may also contribute to data curation or have specific demands on data structure. Meanwhile, data providers may use the aggregated data themselves. There is also a direct relationship between users and individual RIs, which can have spill-over effects on the functions of the platform as an intermediary (see Figure 1).

Figure 1. Relationship among the major actors is complex



On the left is a simplified scheme illustrating the central role of the digital platform as a data aggregator and controller. On the right one can see the more complex picture of interactions and feed-back between the three principle groups of actors.

2. Findings, observations and analysis

A number of key issues emerge from the complex picture of the relationship between actors and are influenced by the different phases of a platform's development. Findings from the case studies have shown the importance of addressing the following issues:

- *Objective setting* starts early in the conceptualisation phase, but is influenced in different ways by different actors throughout all the phases;
- *Data* is the foundation of such initiatives. Data structure, curation, maintenance and expansion are crucial but challenging at different phases;
- *The platform* presents the data, interacts with the users and in some cases it also engages RIs and can provide the focus for developing an eco-system of different actors;
- *Value*: like the RIs whose information they aggregate, the digital platform initiatives face questions of sustainability and making the value proposition to justify public investment – which often means measuring and demonstrating impact;
- *Emerging digital tools*, which can open new possibilities for more efficient automation of some activities or for providing new services;
- *International co-ordination*. As these digital RI platform initiatives are communicating across borders and applying new digital tools, the need for international co-ordination and interoperability is increasing.

2.1. Objective setting

Ultimately data collection and dissemination is what these initiatives do. However, starting with data considerations without prioritising overall aims and objectives can be overwhelming. These primary aims need to inform: the definition of RIs to be included, the categorisation system, the specific data set to collect for a single RI entry and how that varies in different categories, and how the evolving landscape of RIs is incorporated into the project. Considering the usually limited financial and human resources, it is important to set rational objectives before taking on an ambitious programme of collection of data.

Objectives for the initiatives usually address, either explicitly or implicitly, three key questions – what is it? who is it for ? what is it for? Though the main objectives are usually set during the conceptualisation phase, it is important to see how it these are actually followed up and implemented in the subsequent phases of database and platform development and to re-interrogate them at regular intervals as the initiative evolves.

2.1.1. Key questions

What is it? – infrastructure-as-a-service (IaaS) or platform-as-a-service (PaaS)

The initiatives define themselves differently. At the extremes, there are the two distinct categories that for better understanding can be defined by borrowing terminology from the field of cloud computing: infrastructure-as-a-service (IaaS) or platform-as-a-service (PaaS).

In the case of IaaS, the initiative sees itself as a public infrastructure that offers comprehensive meta-data on a defined collection of RIs. An example would be a database that contains top quality structured meta-data on all forms of RIs across all research areas in a country or region. In contrast, a PaaS-type initiative focuses more on the functions and services of the platform, such as connecting users and RIs, providing data analysis and consultancy. PaaS data collection does not need to be as exhaustive as for an IaaS, as long as the data is sufficient to support the services.

In practise, the initiatives included in this scoping study are positioned differently across the spectrum between IaaS and PaaS. Initiatives that aim to build a comprehensive database may also offer analysis services, while those that aim to provide added-value services also pay attention to the quality of their data. Their positioning is strongly influenced by their original mission. Many of the initiatives started with government mandate – such as promoting open science, fostering open access, or connecting research and industry. Data provision alone is not enough to accomplish such aims and this is where platform services are important. In contrast, some initiatives started from a principal requirement for good systematic data for analysis by the main stakeholders, in which case their nature is more that of an IaaS.

Going in either direction has different implications. For an IaaS-type structure, it implies a lot of work to ensure comprehensive and good quality data and engagement of data providers, while for PaaS key tasks include understanding user needs and developing service tools. This difference is crucial, as case studies have shown that it is very ambitious and challenging to be both, i.e. a database with all the data and services to serve all the stakeholders. As in practise most initiatives are hybrids, it is important to be clear on the priority amongst different objectives. An overly ambitious initiative that tries to do all is set up to fail.

Case studies have also shown the potential for linking different IaaS and PaaS activities. For example, a comprehensive database (IaaS) could be built at government/ministerial level together with minimal service interfaces, which allow professionals at institutional level to extract some of the data and support their own platforms for research or mapping services (PaaS).

Who it is for – users and more

Cases report a variety of users, including the scientific community, private sector actors, funders and administrators, policy makers and RI information specialists. Primary users, who may also be funders, normally play a key role in influencing the design and implementation. Identifying (and consulting) users in relation to overall objectives is critical.

Cases studies have also emphasised the need for continuous engagement of all key stakeholders, notably data providers, which may be RIs, institutions or national organisations. In some cases it proves to be relatively easy to secure commitment as there is a clear benefit for the data providers, such as raising their RI profiles or connecting them to more users. In other cases it has been more challenging and necessitated lots of communication or engagement efforts. This is especially so for cases that are principally within the IaaS category, which require more extensive inputs from data providers for whom the value proposition is not always clear.

What is it for? – typical use scenarios

Some cases also include typical use scenarios in their definition of objectives – e.g. planning research projects, establishing contacts across sectors, checking RI investment – which later reportedly help to guide implementation and provide services to stakeholders.

Many cases pointed out that information on RIs, when openly available, has value of its own right and may lead to a much wider variety of use scenarios than initially anticipated. Use scenarios can be replaced by real use case descriptions as a platform becomes established and these, in turn, can help to make the value proposition to a variety of stakeholders (see ahead).

2.1.2. Follow up and implementation

Once set, it is important to make sure that objectives are followed up and implemented throughout the different phases of development. Objectives should be used as an active strategic management tool instead of serving merely as a static reference for *ex post* evaluation.

The case studies demonstrate that having a set of concise and prioritised objectives helps to engage the target users, communicate with key stakeholders, specify future directions and make the best use of resources. This is illustrated with collated findings from the case studies in Table 2.

Table 2. Implementation of objectives with key stakeholders and reported implications/benefits

Phase	Measures	Implications
Conceptualisation	• Define scope of work based on what the initiative is (e.g. more IaaS or PaaS); • Consult with who it is for (e.g. know what they need); • Envision and develop tools for what it is for (e.g. how to get data, data standards and interface, user survey and monitoring tools, etc).	• A clearer positioning of the initiative; • Stakeholder ownership; • A better understanding of what is expected and what is realistically deliverable; • Optimise resource planning; • Standardisation and preparation for interoperability.
Implementation	• Engage key stakeholders for data curation; • Platform services design and tests among stakeholders.	• Engagement efforts required may differ with different objectives; • High data quality and input rate, if stakeholders are engaged; • Active stakeholder engagement may reduce the overall workload for the project team.
Operation	• Understand how the stakeholders are using the initiative; • Engage stakeholders for data maintenance; • Consult for future expansion; • Disseminate; • International co-ordination.	• Create value and impact for stakeholders; • Help to improve data quality and service; • Optimise planning for data or service expansion; • Raise RI profile to the right audience.
Evaluation	• Evaluate the initiative for what it is; • Design evaluation with consideration to stakeholders (e.g. workload for data providers, privacy for industries).	• Avoid expectation discrepancy in evaluation; • Evaluate without creating barriers for stakeholders.

Box 1. Objective setting and implementation of the Canada Foundation for Innovation (CFI) Research Facilities Navigator

The Navigator started with two main objectives: 1. a public relations objective: to demonstrate that the universities funded by CFI are willing to work with the private sector to foster innovation; 2. a utilisation objective: providing a tool for building collaboration between stakeholders, particularly between universities funded by CFI and the private sector. The implementation of these two objectives relative to the different phases of the development of the Navigator are summarised below.

Phases	Public relations	Utilisation
Conceptualisation	• At present, Navigator only includes RIs funded by CFI	• Consultations with private sector and universities to settle essential and simple principles on data;
Implementation	• Objectives are simple and straightforward, and provide a clear value proposition for universities, thus facilitating engagement and data acquisition;	
Operation	• Extensive participation of Universities communicated a clear message of CFI funded RIs' willingness to collaborate; • In turn, this creates a dynamic of attracting more entries and keeping entries updated. The capability of the platform is being broadened to handle more diversified contents.	• Understand what works with the private sector in terms of usability and expansion; • Understand how the Navigator is being used; • Consider broader coverage of facilities, so long it creates value for the users.
Evaluation	• The public relation value is simply demonstrated by the number of entries and statistics on web traffic.	• Monitoring and evaluation designed on the basis that it does not create too much workload too soon for the universities and protects the private sector's interests.

2.2. Data

Data is the foundation for these initiatives and is reported frequently in the case studies as one of the areas that requires a lot of investment and work, which can easily be underestimated. Data-related work is required throughout the different life cycle phases of a platform and needs to be combined with continuous stakeholder commitment in order to build a robust database. Case studies have highlighted a few key stages for data management: defining the scope of data, data acquisition, data maintenance, and later, data expansion.

2.2.1. Defining the scope of data

This relates to the definition of RIs and criteria for RI inclusion. It also covers categorisation of RIs of different types or in different science domains, what kind of data to collect for a single RI entry, and the establishment of meta-data model.

Among the cases, the scope of data is often defined *de novo* and varies depending on different objectives. Cases more of an IaaS nature may need to go through a process of consultation with multiple stakeholders in order to have a full picture of the scope of expectations and come to a consensus between what is desirable for the stakeholders and what is realistically deliverable. Cases more of a PaaS nature reported a more focused

consultation process with targeted stake-holders that led to the definition of more flexible principles on data requirements.

Sometimes the scope builds on what is available already, such as national RI roadmaps or existing databases. Such cases start more smoothly, but may still encounter the need to re-define data requirements as they develop further, especially if they need to expand to cover a larger variety of RIs.

Consultation with key stakeholders is considered to be very important not only for ensuring that the appropriate data model is adopted but also for developing stakeholder ownership, managing expectations and establishing channels of communication that can pave the way for future developments and standardisation. However, it can be a lengthy and resource-intensive process, especially for IaaS-type initiatives. It also, in some cases, would be helpful to make use of the categorisation work already done in other initiatives. Indeed, case studies revealed some communication and collaboration across European initiatives on common definitions, terms or categories.

2.2.2. Data acquisition

The data acquisition stage includes the identification of eligible RIs, collection of data from the RIs and data input to the system.

Eligible RIs are identified usually by RI owners, such as universities, institutes or national bodies with responsibility for RIs. Academic associations, already enlisted RIs, or existing databases can also be valuable information sources. The agreed standardised RI meta-data is, in most cases, collected using an on-line information collection form, which is then quality-checked by the initiative operator and loaded into the system. In some cases the data is entered directly into the system by the provider and quality checked by the operator before publishing.

A key issue for this stage is the engagement of RI data providers. For most of the cases, data is provided on an open and voluntary basis. Various measures are taken to encourage participation, ranging from direct communication (such as calling RI owners or managers) to networking or training events (workshops and conferences). This can put a high demand on the time and human-resources of the initiative.

Case studies show that, for PaaS-type cases, if they have a persuasive objective, such as linking to specific users or use scenarios, which appeals to the data providers, it is easier to engage them. PaaS-type cases usually collect a more focused set of data, and consequently find it easier to manage the workload for both the data provider and themselves. For IaaS-type initiatives, as they focus more on the data itself and may require a more extensive set of specifications, it can be more challenging for them to get a satisfactory data input rate. Digital tools for automated data mining have the potential to relieve some of this data acquisition work in the future but are also not without their drawbacks (see ahead).

2.2.3. Data maintenance

Data maintenance mainly relates to the updating of existing data, as some RI information, such as contacts, is prone to change. Routine data maintenance is usually done on a yearly or twice yearly basis and involves sending out update notifications to the RI data providers.

To achieve a better feedback rate on updates, the cases reported using measures such as more targeted update notifications instead of generic ones, or providing online channels for users to submit an update request on specific RI entries. Once again, effective communication with stakeholders is the key to keeping data up to date and relevant to users. Data maintenance in a well-structured core database can allow synchronisation with other linked databases and platforms.

2.2.4. Data expansion

Data expansion can entail an expansion of content for existing entries, or an expansion of the catalogue to cover a wider scope of RIs, e.g. RIs of new kinds, from new science domains, or new geographic areas.

Expansion is inherent due to the evolving nature of RIs. However, plans for expansion need to be in line with an initiative's principle objectives and agreed by the main stakeholders, as data curation and changes of the overall data model can be resource-intensive.

Box 2. Mapping the European Research Infrastructure (MERIL)

MERIL aims to provide an inventory of openly accessible research infrastructures in Europe across all scientific fields. It consists of a database and a public portal where information about research infrastructures is provided in a standardised format.

In the initial phase, a considerable amount of time and a broad consultation were taken for defining the scope of data to be collected. This consultation has allowed the development and consolidation of a set of definitions, glossaries, classification of RIs, and a meta-data model that have subsequently been taken up by several national initiatives and databases. This outcome is considered to be one of the strongest added-value aspects of MERIL.

As a European level initiative, data curation for MERIL required significant resources (time and human) and specific skills and knowledge. Centralised investment was complemented by the creation of a network of National Data Intermediaries (NDI) and RI co-ordinators in virtually all European countries. MERIL illustrates the importance of constant stakeholder engagement and co-ordination. Data input to MERIL is supposed to be done by individual RIs on a voluntary basis. The absence of an incentive mechanism for encouraging data submission poses a challenge.

Ensuring data quality and comprehensiveness is a constant task for MERIL. The definition of comprehensiveness changes with the evolution of RIs across different domains. This implies that the initiatives, such as MERIL, should be considered as part of a long-term and evolving ecosystem of RIs for enabling science.

2.3. The platform

The platform acts as the interface between the data and the users. In line with their overall objectives, platforms take quite different forms across different initiatives, ranging from a simple search and display tool providing meta-data to complex systems that allow online reservation of facilities by users. Understanding primary users is fundamental to developing an effective platform.

2.3.1. Platform design and functionality

Most platforms are designed in house, often starting *de novo*. Some, but not all, went through a process of testing with selected groups of users to gather feedback during the conceptual and implementation phases.

A core functionality shared across all the initiatives is to provide information to users. To do so effectively, a search function required. Some initiatives have refined this so that structured searches can be carried out for different domains, categories or regions, and some have gone further and provide a key-word search.

The platform design may be as simple as is necessary to generate a table of relevant information content, which can be readily exported into other systems. In some cases, the design and display is much more sophisticated. Some platforms aim to raise the profile of individual RIs and can provide multi-media or geographic mapping presentations of the research infrastructure landscape.

2.3.2. Platform improvement

Several cases reported platform improvement as a major task for the near future. To achieve this, it is important to understand who the actual users are and how they are using the platform in real life. Some cases are using web analytical tools to monitor platform usage. However, as most cases are open access and do not require user registration, it is challenging to know how they are actually used by site-visitors.

It was pointed out in interviews that spontaneous user feedback is usually on design faults or functions that do not work on the platform. To understand more systematically what works for users and what they would like, proactive surveys are the main tool. However, surveys are time and resource consuming, and need to be done carefully to respect the privacy and workload of those being surveyed.

2.3.3. Platform as part of a RI system

Most of the cases have taken a simple and straightforward approach to platform design – a stand-alone web portal that is more or less sophisticated, supported by a structured database. However, there are also cases where a larger distributed system is built around the core database and platform, to provide more added-value services (see example in Box 3).

Box 3. Zone for Equipment Utilisation Service (ZEUS)

In Korea, the demand for the sharing equipment has increased since 2008 when the national policy direction shifted from input-oriented to utilisation-oriented investment. At the same time, it was necessary to address efficiency in R&D equipment investment and the shortage of RI engineers. ZEUS was established to address these needs and promote wider use of RIs. It has a main site – ZEUS – which promotes equipment sharing through an open searchable database and online reservation function. It also has four other sites around it, providing complementary functions:

Objective	Platform	Function
Promotion of shared access	ZEUS	Enables search and reservation of national R&D facilities and equipment all over the country
Strategic investment	RED (Review, Evaluation and Deliberation for facilities and equipment)	System for reviewing equipment investment proposals at both budget compilation and execution stages
Training of engineers	SEE (School of Equipment Engineers)	Improves social awareness of engineers for research facilities and equipment; Prepares certification for qualified engineers; Supports project to help employment of qualified engineers.
International collaboration	WOLF (World Of Large Facilities)	Introduces international large scale-research facilities to promote co-utilisation; Introduces Korean large scale-research facilities to international users.
Research and RI linkage	BRAIN (Bright Research And Infrastructure Network)	A service that connects research project, researcher, and research equipment together, e.g. information on the researcher of and equipment used by a project, and vice versa.

2.4. Value proposition(s)

Value was frequently mentioned in the case interviews. A good value proposition facilitates communication of objectives to stakeholders and engages them in a more meaningful way. This in turn helps with the sustainability and evaluation of the initiatives. Value can come from both the data itself and the platform. Enabling access to RIs is a primary aim of all of the cases that were interviewed and this is considered as having important value, although it can be challenging to quantify.

2.4.1. Value from data

Data is valuable, especially when it is open, comprehensive, high-quality and well-structured. Once openly available, data can be used by a wide spectrum of users, within and beyond the research and policy community. Some cases have reported that the use of the data had exceeded their expectations and created many unexpected outcomes in addition to providing useful information to targeted users.

The comprehensiveness of their data enables some initiatives to use them for more strategic purposes such as RI mapping or analyses for RI investment. This can lead to direct involvement in strategic projects that can in turn feed-back into the initiatives' own future plans.

The development and sharing of a high quality structured data framework contributes to broader community efforts on standardisation, categorisation and terminology development. This promotes interoperability and can help provide a robust data source for other initiatives and systems that may be more focussed on providing platform services.

Box 4. Marine Research Infrastructure Database (RID)

EurOcean RID is a catalogue of existing facilities which are dedicated to a broad range of marine science activities in Europe. It provides information on the main characteristics for each facility, as well as the links and contacts to access further details as provided by the operator.

Being one of the most comprehensive databases on marine research infrastructure, RID is able to provide valuable input to European level research projects and initiatives in related fields. At the same time, by being involved in research projects, RID can further populate its database, cover new thematic areas and access resources for appropriate expansion.

It was highlighted in the case study that the involvement in research projects and initiatives helps to maintain the relevance of RID, which in turn keeps the included RIs relevant, therefore creating a new incentive for continuous engagement from the RIs.

2.4.2. Value from the platform

Value from the platform mainly comes from the services. As noted previously, most of the cases in this study focus on providing information via a website, although there are variations in web design and search functions. Other web-platform services that are variously provided include services for profile-raising, analysis, integration and access.

Some cases reported that the highlighting of RIs on the website can help with profile-raising or dissemination that is much appreciated by the RIs. Therefore some initiatives are offering a front page RI photo-gallery, multi-media display, social media channels or promotion videos for the RIs. This is particularly useful when promoting RIs to users outside of the science community, who are not well aware of the capabilities of the RIs.

When included, data analysis services are usually provided to a limited group of strategic stakeholders, for purposes such as mapping, capacity analysis or investment evaluation. Data integration services can help to embed the database in other systems, such as the processes for project planning and implementation.

Box 5. Austrian Public Database of Research Infrastructures

The Austrian Public Database of Research Infrastructures (APDRI) presents over 950 selected research infrastructures that are available for collaboration in research and development. It has three major objectives:

- To act as an information-sharing platform for establishing future co-operation in science and innovation;
- To promote and represent selected research infrastructures and their role in science and innovation;
- To promote transparency of research and research infrastructures in Austria.

It was noted in this regard that, besides data, a good platform depends on the search engine, the design, the user interface and its terms of use all of which need to be tailoring to meet users' needs. APDRI features a gallery of representative RIs on the front page and a special gallery site, which attracts a lots of visits.

2.4.3. Enabling access

Providing up-to-date and accurate descriptive information is considered an initial and necessary step for enabling access to RIs. Potential users (including public and private sector researchers) do not necessarily know what RIs are available, where they are, and how to access them. By acting as a portal, providing RI specifications, geographic information, contacts and terms of use, the initiatives can catalyse co-operation and collaboration.

Some initiatives apply thresholds for inclusion, such as only including openly accessible RIs or only those that are open to collaboration with industrial or economic sectors. A challenge for such a selective approach is that it can be difficult to know how actually the users are using the information for RI access purposes, as the users do not necessarily need to go through the platforms to contact individual RIs. More insight into how users make use of the information they obtain would potentially help the platforms to provide better services (and also eventually help to build a more rational impact assessment process.)

Some initiatives permit users to send a message to the RIs via their platform, while some initiatives have taken a step further by providing full reservation services, via which the users can register, login and reserve access to listed RIs. These services may incorporate tracking of usage and online user review and rating systems for the RIs. Providing reservation services can also present challenges, such as establishing prices or reservation priority, and possibly introduce more red tape for individual RIs. Nevertheless, it is notable that in this area of reservation services, a number of third party private companies are emerging, which suggests that there is added value to be extracted.

Box 6. ZEUS, Q-Reserve and Qwings

ZEUS provides search and reservation services for national R&D facilities and equipment all over Korea. It links government funded facilities and equipment, and provides reservations for researchers from public and private sectors, both online and through mobile APPs. Users can also share reviews and feedbacks of facilities and equipment through the platform. Reportedly around 5,300 reservations and utilisations are generated per day.

Presently the listed RIs are open and free to all users. But it is recognised that it will be difficult for RIs to provide a completely free public service in the long term An appropriate incentive structure will be required for RIs operators to help them develop financially sustainable business models whilst maximising access.

Third party private service platforms are now emerging in a number of countries. Q-Reserve Inc., a spin-out company from McMaster University, offers multiple services for identifying and managing research resources. Qwings, a start-up in Shanghai, offers an online sales platform for RI services (predominantly testing and prototyping services), where users can browse, reserve, and review RI services, paying either in money or government tech-coupons.

2.4.4. Sustainability

Sustainability of digital RI platforms is influenced jointly by how they are creating value and how they are funded. For initiatives that are supported by institutional funding, and are considered valuable by an identified user community, for either their data or platform, sustainability is not considered a major challenge. Sustainability is more of a concern for initiatives funded on a short-term project basis.

It was also noted that sustainability or longer term prospects may be an important consideration in stakeholder engagement. Stakeholders, including the crucial RI data providers, are generally more confident and willing to engage with initiatives that are stable and will exist for a long term.

Efficient use and/or sharing of already available resources, such as existing stakeholder networks or existing databases from other departments or institutions, can also help with sustainability.

Ultimately, sustainability depends on having a viable business model and a clearly articulated value proposition for all stakeholders - funders, data providers and users. This model should include some degree of flexibility and is likely to evolve during the life-cycle of a platform. For a detailed consideration of the related issues see the recent GSF report on Business Models for Sustainable Data Repositories (OECD, forthcoming a).

2.4.5. Measuring value

For many initiatives, routine performance indicators include: the number of RIs in the database, quality of the data, and access statistics. For platform services, measuring the overall value and impact can be difficult and resource-intensive as some objectives (e.g. promoting connections and collaboration, profile-raising) are hard to quantify.

However, to ask what kinds of value have been generated by the initiatives is a relevant question that feeds back to objectives and sustainability. Finding ways to measure value without creating barriers (e.g. extra workload, privacy protection) remains an important issue for the initiatives. Most of the cases in the present study are already taking, or

considering taking, proactive measures, such as conducting user surveys, to help address the issue of value to users.

2.5. Emerging digital tools

Many digital tools are being employed or considered by the initiatives that were included in this study. The main areas of application are in increasing the efficiency of data curation or enhancing platform services.

Automatic data mining can be used to retrieve information automatically from individual RI websites, but for this to be used effectively it requires RIs to code their information in a standardised format.

Application program interfaces (APIs): an API provides a standardised machine-readable interface for data input and output. It is considered important especially for IaaS-type, data-focussed, initiatives. It facilitates connection of a database and platform to different systems, and makes it easier to update the content of the database (e.g. updated once, synchronised in all the other connected systems). APIs should ideally be developed at an early stage, along with the development of data models.

Unique identifiers/persistent identifiers (UID/PIDs): a UID/PID can be implemented to establish a standardised, machine-readable format for identifying a RI. Once applied in a larger scale, it removes ambiguities and enables tracking of an RI throughout the scientific process (e.g. to know how a selected RI is linked to projects and publications). An important prerequisite to the adoption of UID/PIDs is a stable and universally accepted definition of what a research infrastructure is.

Mobile applications (apps): some initiatives have developed mobile apps to enable access their services via mobile phones.

Box 7. The Finnish Research Infrastructures Service

The Finnish research infrastructures service (FRIS) is a databank describing and showcasing research infrastructures and their services in a unified manner. FRIS is a part of the Open Science and Research initiative in Finland. Automation and the use of state of the art digital tools, is an important feature of the ongoing development of FRIS, which aims to function as a portal for distributed databases of RIs.

Automation is envisioned by FRIS at different levels, including: automatic data update across inter-linked databases; automatic integration of feedback on meta-data content; and, automatic RI identification in project proposals and publications.

To achieve this, some of the architecture is already in place, including an API for data-linkage with other systems and a persistent identifier (PID) for identifying each RI. Measures to enable cross-referencing across different databases are also being looked at.

Introducing further automation is seen as mechanism to: increase the data quality and promote long term development of the distributed databases; facilitate standardisation across databases; and provide the possibility to link projects and research outcomes with selected RIs, making it possible to have a clearer picture of the impacts of these RIs.

However, it was stressed in the interviews with FRIS that it is difficult to decide what can be automated, and requires a lot of effort on standardisation and co-ordination across different systems.

2.6. International co-ordination and interoperability

Continuing the previous consideration of emerging digital tools, it was pointed out by several of the survey cases that the application of such tools needs careful planning. To be successful, these tools require a standardised set of terminologies and parameters for the data, which will probably be most useful if they are determined and adopted in an internationally co-ordinated manner. Such standards are critical for interoperability.

Besides co-operation on terminologies and parameters of data, it was noted that an effort to harmonise different practices of data acquisition and curation across countries, e.g. agreeing common definitions and sharing of good practices, would help to produce a more comprehensive and comparable set of data for both national and international initiatives. In this context, national and international legislation on open information and data is developing rapidly, and may affect transnational initiatives and create additional work for compliance in some areas.

Box 8. RIsources - Research Infrastructure Portal

RIsources (RI = Research Infrastructure) is a portal operated by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation). It provides quality-assured information on German RIs of any size and type and contributes to co-operation and interoperability efforts by disseminating and applying internationally accepted standards.

The focus of RIsources is on information quality. To ensure good quality, a few essential steps have been taken:

- A list of internationally accepted requirements for inclusion has been agreed. These are considered the main framework of RIsources. Hence, eligible RIs should:
  - offer recognised, established, scientific and technological facilities or services
  - permit free access or regulate access through a transparent selection process and user agreements based on scientific quality and project feasibility
  - be managed according to sustainable principles and have a long-term perspective.
- A sequential consultation process is in place to check whether a RI is eligible for inclusion. Feedback loops on missing information help improve the quality of RI meta-data;
- For included entries, quality checks are repeated on a regular basis to keep the information in the data base correct and up-to-date.

Conclusions

Open science in its broadest sense refers to efforts to make the scientific process more open and inclusive to all relevant actors, within and beyond the scientific community, as enabled by digitalisation (OECD, forthcoming b). It is not only about open access to publication or open data, but is also about access to research infrastructures and related information. This case study has shown that open digital platforms that aggregate RI meta-data and provide a variety of services can have substantial value for a wide range of stakeholders. To develop such platforms effectively, requires careful attention to a number of generic issues:

- Many RI databases and platforms already exist and before developing new ones a thorough analysis of the existing landscape should be performed, noting that RI platforms should be a long-term investment. There may be opportunities to build on existing initiatives and share experiences.
- The development of a set of concise, rational and prioritised objectives that address key questions for the initiative (what it is, who and what it is for), is important for engaging key stakeholders, and should guide the continuous development of the RI platform;
- The amount of data-related work for such initiatives should not be underestimated. It is important to define a reasonable scope of data collection based on the needs of key stakeholders and the available resources. For good data acquisition and maintenance, it is important to keep strong and constant engagement with stakeholders, especially data providers. Shared objectives can help here, though many initiatives pointed out the need for additional incentive mechanisms. Data expansion is natural considering the evolving nature of RIs, and this needs to be aligned with the overall objectives and stakeholder needs;
- Besides providing simple information, digital RI platforms have the potential for delivering many additional added value services. To do so, it is important to understand who the users are and what works for them;
- Data and platforms are valuable assets. It is important for the initiatives to consider how they can create value from such assets, as this will help to engage stakeholder in a more meaningful and proactive way. A well-defined business model, including value propositions for different actors, can provide a foundation for evaluation and long-term sustainability;
- Emerging digital tools open up new possibilities for more efficient data-related work or more value-add services. However, their adoption also requires foresight, planning and investment and the process of implementation may be complicated;
- International co-ordination around standards and interoperability is necessary. This is important for cross-border collaboration in the provision and use of RIs and for automation of data management processes. It should encompass not only terminologies and parameters of data, but also practices for RI identification and data curation across nations.

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Annex 1. Case descriptions

Name [person(s) interviewed]	Coverage	Description
Austrian Public Database of Research Infrastructures **https://forschungsinfrastruktur.bmwfw.gv.at/en** [*Thorsten Barth, Ministry of Science, Research and Economy, Austria*]	Austria	The Austrian public database of research infrastructures (APDRI) presents over 950 selected research infrastructures for collaboration in science, research and economy. It provides incentives for collaborations between research institutions of the tertiary sector or research intense companies to strengthen sustainable knowledge sharing and innovation via research infrastructures.
Canada Foundation for Innovation Research Facilities Navigator **https://navigator.innovation.ca/** [*David Moorman, CFI*]	Canada	The Canada Foundation for Innovation (CFI) Research Facilities Navigator is a searchable online directory of participating research labs and facilities in universities, colleges and research hospitals across Canada that are open to working with business. It started in 2013 with a listing of 150 facilities and has expanded to include several hundred entries.
Finnish Research Infrastructure Service **http://infras.openscience.fi/** [*Juha Haataja and Sami Niinimäki, Ministry of Education and Culture, Finland*]	Finland	The Finnish research infrastructures service, which is currently under development, is a databank for researchers, research infrastructure service providers and funders. The service promotes sharing and openness by describing and showcasing research infrastructures and their services in a unified manner. FRIS is a part of the Open Science and Research initiative in Finland and its service is in a pilot phase with ~300 entries, some of which are located abroad.
Mapping the European Research Infrastructure (MERIL) **https://portal.meril.eu/meril/** [*Ana Helman, European Science Foundation*]	International	MERIL aims to provide an inventory of openly accessible research infrastructures in Europe across all scientific fields. It consists of a database and a public portal where information on ~900 major research infrastructures (RIs) from 28 European countries is provided in a standardised format.
Marine Research Infrastructure Database **http://rid.eurocean.org/** [*Ned Dwyer, European Centre for Information on Marine Science and Technology, Portugal*]	International	The Marine Research Infrastructures Database (RID) is a catalogue of more than 900 existing facilities in Europe which are dedicated to a broad range of marine science activities. It provides information on the characteristics for each facility, as well as the links and contacts to access further details as provided by the operator.
RIsources – Research Infrastructure Portal by DFG **http://risources.dfg.de/home_en.html** [*Stefan Winkler-Nees, DFG*]	Germany	RIsources (RI = Research Infrastructure) is a portal operated by the Deutsche Forschungsgemein-schaft (DFG, German Research Foundation) providing information on over 300 scientific research infra-structures. It provides researchers with resources and services for planning and implementing research projects.
ZEUS **http://www.zeus.go.kr/** **e-Tube** **http://www.etube.re.kr/main/mainIndex.do** [*Kyung-Hoon Kwon and Yong-Joo Kim, NFEC, Korea*]	South Korea	In South Korea, there are two digital platforms which promote access to research infrastructures and specialised equipment. The most comprehensive one is named ZEUS (Zone for Equipment Utilisation Service) operated by NFEC (National research Facilities & Equipment Centre) in the Korea Basic Science Institute and the other is 'e-Tube' operated by KEIT (Korea Evaluation Institute of Industrial Technology). These digital platforms serve to improve the efficiency of research infrastructure and equipment management, while helping users access thousands of facilities and instruments that are distributed in over 600 centres.