Research data management - An overview of recent developments in the Netherlands

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Data Archiving and Networked Services

Research data management

An overview of recent developments in the Netherlands

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This white paper makes the content of that chapter available to those who don't read Dutch. Some references have been adapted.

1. Introduction

This article offers an overview of recent developments in the field of research data management. By its very nature, such an overview can never be exhaustive. Research data management – in short, the proper handling of research information – is in a constant state of flux, both nationally and internationally, and new data services are regularly being introduced. At the same time, it is precisely this dynamism which calls for an overview article of this kind.

Below, we have attempted to map the current state of affairs within the Netherlands. Specifically, we have looked at national developments in higher education and science; commercial services are mentioned where they play a role in these developments, but we do not, for instance, deal with developments in big data outside of the academic world or with the public sector open data initiatives. Here and there, we include examples from specific scientific fields, but it would take us too far afield to deal with the (occasionally profound) differences between these fields in any great detail. We refer readers interested in this topic to (Borgman, 2015) and chapter 2 of (KNAW, 2013). The authors would also like to mention that they have both been employed (in the past or at present) by an institution aimed at ensuring sustained access to research data (see Section 4.4), which may affect the balance of subjects discussed in this article.

Chapter 2 deals with the importance of data management, and chapter 3 introduces and defines certain key terms, such as *data*, *data management plan*, and *research cycle*. The next chapter examines the various phases of the research cycle in more detail: whereas the initial planning of the required data management must obviously take place at an early stage of the research process, various aspects of its execution should be considered during the subsequent phases. The question of how data supporters, like librarians, (can) contribute to the various phases is discussed in chapter 5, which also provides an overview of the various powers in play in the field of data management within the Netherlands.

2. The importance of research data management

Whether your research is performed in a lab, in the field, or at the office, with a large or with a small team, it inevitably involves research information, or data. These data are valuable, and deserve to be properly managed. Over the last few years, the notion that good data management is an important part of scientific practice has increasingly found widespread acceptance.

The influx of data generated by scientists is rapidly growing, due in part to the great increase of relevant information from social media and open public sector data. The report *Riding the Wave*, published by the European Union (High Level Expert Group, 2010), outlines the consequences, opportunities, and challenges offered by this 'tidal wave of data':

> *The benefits are broad. With a proper scientific e-infrastructure, researchers in different domains can collaborate on the same data set, finding new insights. They can share a data set easily across the globe, but also protect its integrity and ownership. They can use, reuse, and combine data, increasing productivity. They can more easily solve today's grand challenges, such as climate change and energy supply. Indeed, they can engage in whole new forms of scientific inquiry, made possible by the unimaginable power of the e-infrastructure to find correlations, draw inferences, trade ideas, and information at a scale we are only beginning to see. For society as a whole, this is beneficial. It empowers amateurs to contribute more easily to the scientific process, politicians to govern more effectively with solid evidence, and the European and global economy to expand. But there are many challenges. How can we organise such a fiendishly complicated global effort, without hindering its flexibility and openness? How do we incentivise researchers, companies, and individuals to contribute their own data to the e-infrastructure – while still trusting that they can protect their privacy or ownership? How can we manage to preserve all this data, despite changing technologies and needs? How to convey the context and provenance of the data? How to pay for it all?*

In addition to these opportunities and challenges, however, research also has its risks. Recent cases of fraud and the subsequent investigation by the Schuyt Committee (KNAW, 2013) have shown that research data are not always managed and shared in an appropriate way. This may cause significant harm to the scientific community.

Funders and policy makers in the world of scientific research have responded to these developments by formulating data policies on the international, national, and institutional levels.[1] Important themes in these policies are the transparency and verifiability of studies, and the

1 An overview of the data policies of Dutch universities can be found at https://www1.edugroepen.nl/sites/RDM_platform/Lists/RDM bij universiteiten in Nederland/AllItems.aspx.

reusability of research data. A more focused pursuit of these goals will lead to better and more efficient research, as building on existing data can speed up research projects, and not having to generate the same data all over again may lead to significant financial advantage.

In fact, the Netherlands Code of Conduct for Academic Practice (VSNU, 2014) laid the groundwork for these notions of transparency and verifiability: “Presented information is verifiable. Whenever research results are published, it is made clear what the data and the conclusions are based on, from where they originate and how they can be verified.” Or, as the strategy outlined by DANS (2015b) states: “The integrity of scientific practice benefits from transparent research processes, and responsible data management is a part of that.”

Aside from these general goals, researchers themselves profit from a proper documentation of their work processes and data. This may seem redundant, since researchers in most fields are quite familiar with the principle that a publication should include a description of the methodology employed in the study. This description, however, does not always provide sufficient detail for a researcher to recall, for instance, exactly how he or she obtained a certain measurement, or which query in the statistics package is linked to a certain table included in the publication. Other interested parties will have even more difficulty finding this information, if it is even possible at all. This means that they cannot, in fact, rely on these data – a missed opportunity for reuse and citation.

3. Key terms

Data management is a young field, and the set of relevant terms is still in development. Organisations often use their own particular definitions of important concepts like ‘data’ and ‘data management’. In a sense, this article does the same, but the authors do not intend to take a very specific stance, and readers may operate in different circles with their own conventions. That being said, we will provide definitions of a number of key terms for the purposes of this article: data, metadata, FAIR, the research data life cycle, data management or RDM, data management plan or DMP, and archive.[2]

First, let us consider the actual research information, or **data**. These may be facts, observations, interviews, recordings, measurements, experiments, simulations and software; numerical, descriptive and visual; raw, cleaned up and processed; they may or may not support an actual or intended publication; and may be stored and exchanged in various formats on various storage media.[3] This list, while not exhaustive, is intended to offer points of recognition for all research disciplines, since reusability, verifiability, and transparency are relevant across the board. Non-digital data, such as paper surveys or body tissue, will not be covered in this article.

Just as bibliographic information is added to books and articles, similar information is added to data. This information is usually referred to as **metadata**. Metadata, then, are information regarding specific data, allowing users to find these data in online portals, for example. Both generic and domain-specific metadata standards exist; the latter often give more descriptive detail, but are rarely supported in larger, more general search portals. The line between metadata and documentation cannot be sharply drawn: the codebook used in the social sciences to define the variables used in a research project, for example, falls somewhere in between the two. More important than the terminology, however, is the point that this contextual information must be made available to allow users to interpret the data in the right way. Rich metadata will enable interested parties to better determine whether or not a data collection is relevant and usable for their own research. Several research communities maintain a metadata standard for their particular field;[4] this contributes to the findability and efficient use of existing data within a domain. The notion that metadata should always be public, even if the data themselves are not or only partially accessible, is widely supported.

2 These definitions of data, data management and metadata are derived from “NWO Institutes Data Management Policy Framework” (unpublished). The description of the research life cycle has been derived, with permission, from the “Essentials 4 Data Support” course; see http://datasupport.researchdata.nl/en/start-de-cursus/i-definitions/research-lifecycle/. For more terms related to data management, see http://datasupport.researchdata.nl/en/start-de-cursus/i-definitions/data-jargon/.
3 This is the definition used in “NWO Institutes Data Management Policy Framework” (unpublished).
4 An overview of metadata standards for various domains can be found at http://rd-alliance.github.io/metadata-directory/standards/.

In 2014, the **FAIR principles** for data were introduced. These principles, if properly implemented, will ensure that data is *findable*, *accessible*, *interoperable* (it can be compared and combined with other data), and *reusable*. The central ambition underlying the FAIR principles is to attain these goals for both humans and machines. Wilkinson et al. (2016) describe the ideal: data that are so richly and systematically documented that they become machine-actionable, meaning that an 'autonomously-acting, computational data explorer' can independently determine how useful a digital object will be for a given task, and whether the licence attached to the object will allow access and reuse. For the time being, this is still a long ways off for many fields, and the challenge at hand is to convert the FAIR principles into concrete criteria and guidelines for data-producing researchers and data service providers. Good data management is one way to support the FAIR principles.

Research data have a long lifespan, often longer than the period between their creation and the writing of the scientific publication for which they were intended, and the data's function and value change from one phase of the research cycle to the next. A **research data life cycle** is a tool that can be used to map these different phases, how they connect to one another within the lifespan of research data, and how the choices a researcher makes in one phase will influence data quality in another phase. Using a life cycle helps to shift the perspective from the short to the long term: what do we want from these data? How can you ensure that the choices you make in collecting your data are robust enough to make preservation and reuse possible?

Traditionally, researchers in most fields are more focused on publishing articles than on the information they generate and use. If we want to shift that focus, the cyclical model outlined below, based on the UK Data Archive (UKDA)'s research data life cycle, will prove useful.[5] If we focus on the data, the different phases in this model are generic enough to be recognisable by most researchers and other involved parties.

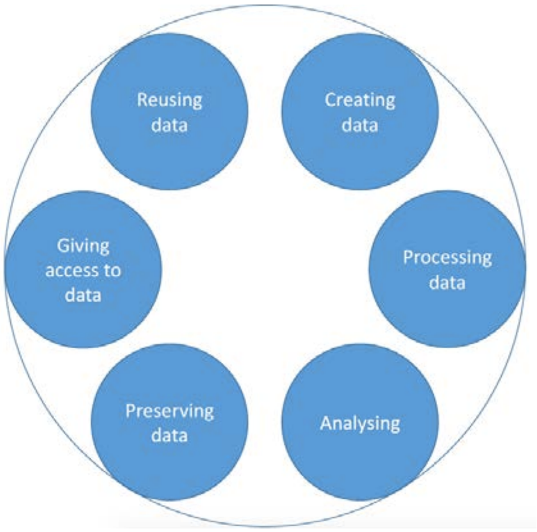

Figure 1: Research data life cycle (based on UKDA)

5 http://www.data-archive.ac.uk/create-manage/life-cycle.

Other research data life cycles, more specifically aimed at the needs of a specific group of users, are also available. Some examples can be found on the 'Essentials 4 Data Support' course website.[6] In this article, we will follow the six phases of the life cycle outlined in Figure 1. This model is, of course, an abstraction: the different phases cannot be strictly delineated, and valid reasons may exist to return to an earlier phase during the course of one's research. Moreover, several data activities, such as storing data, are spread out over more than one phase. Before we move on to examine the first phase of the cycle, however, there are a few other frequently recurring terms to introduce.

Data management concerns the full trajectory between the creation or collection of data to their storage, maintenance, preservation, publication, and/or long-term preservation. No distinction is made here between the different goals researchers might have for storing their data, such as verification, replication, reuse, or combination with other data.[7] Research data management and RDM, meanwhile, are synonyms of this term. The term 'data stewardship' has also been used to mean the same thing, whereas others limit that term to activities related specifically to sustainability. High-quality, well-documented data management results in the transparency needed to make data verifiable.

A **data management plan** or DMP is an addition to a research plan. It describes, among other things, what kind and how much data the project is expected to produce, which of these data will be stored for the long term and how, and which conditions will have to be met to access these data. If applicable, it also describes the hardware and software needed to use the data. A DMP maps out the entire data life cycle. It is a dynamic document and frequently needs to be adjusted over the course of a research project (if access to certain sources is unexpectedly granted or denied, for example, or if new parties join the project consortium). At the time of writing, the research funders NWO, ZonMw, and the European Commission regard this dynamism as a matter of course. Although a DMP should be written shortly after the project submission has been approved, it does not, then, have to be 'right the first time'. Research institutions and departments that require a DMP generally hold to a similar principle.

6 http://datasupport.researchdata.nl/en/start-de-cursus/i-begrippen/research-lifecycle/.
7 This is the definition used by NWO in the (unpublished) "Beleidskader Datamanagement NWO-instituten".

Data management plans

A data management plan or DMP is a useful stimulant for researchers to obtain advice and reach agreements concerning, for instance, legal aspects (who can do what with these data?) and technical facilities (which hardware and software do I need?) at an early stage. Conversely, being involved at the planning stage is a good way for the research organisation, supporting departments, and external service providers to streamline the intended work processes, as it allows them to see what is coming and enables them to offer timely advice to the researchers. Data archives, for instance, like to be consulted even at this early stage about potential future data deposits, so they can inform researchers about the appropriate file formats, metadata, and the like. As with data life cycles, a large number of DMP templates are available globally. Based on the templates offered by Dutch and European research funders, DANS has extracted and listed the key elements a DMP should include at a minimum; see the table below (DANS, 2015a).

1	**Administrative information**
1.a	Project title, principal researcher, funder(s), date of this plan and of previous versions
1.b	Who is primarily responsible for data management?
2	**Describing the data**
2.a	Are existing data reused or are new data generated?
2.b	What type(s) of data is concerned; file size; growth rate?
3	**Standards and metadata, or: everything required to find and use the data**
3.a	Which metadata standards are used (findability)?
3.b	Which coding etc. is used for enabling future linking to other data (interpretation, interoperability)?
3.c	Which software and hardware are used (interpretation, usability)?
3.d	What is documented and stored to enable replication?
4	**Ethical and legal**
4.a	In collecting or generating data, how is required permission obtained from the data supplier/ test subjects / ...? Which restrictions, if any, apply during research?
4.b	How are sensitive data protected during and after the project?
4.c	What are the agreements in the case of stakeholders leaving (early)?
4.d	Are data available Open Access after the project, perhaps after an embargo period? If not, which conditions apply?
5	**Storage (during the project) and archiving (after the project)**
5.a	How is sufficient storage and back-up capacity organised during the project, including version management? Are the expenses for this covered, and if not, ...?

	5.b	Where, and how long after completing the project, are data available for follow-up research and verification? Is this a Trustworthy Digital Repository with an international certification? If not, how will the data be findable, sustainably accessible and usable? Consider metadata and persistent identifiers, such as DOI, Handle and URN.	
	5.c	Are the expenses for (preparing the data for) archiving covered?	

Related to DMPs, we must introduce one more key term before we move to the next chapter: **archive**. In discussing the storage of data, it is prudent to differentiate between saving data during the course of a research project (‘storage’) and saving data for the long term when the project has concluded (‘archiving’ or ‘preservation’). Both phases may involve the exact same data, but different agreements may apply, for instance, to the conditions of access to the data and/or the responsibility for the management of the data. In this article, the terms ‘archive’ and ‘repository’ are used interchangeably. The title of ‘Trustworthy Digital Repository’ or TDR, meanwhile, applies to archives or repositories that have been certified as such.

4. The research data life cycle

In this chapter, we will examine the various phases that researchers and their data move through during the course of a research project, with the caveat that significant differences exist between and even within the various fields.

4.1 'Creating data' phase

In Figure 1, the reuse and generation of data have been intentionally placed side by side, at the top. At the start of a new research project, a researcher should ideally seek out existing data first, before moving to generate or collect data (again) themselves. Research funders, too, are increasingly aware of the potential for reuse of data, since this could save both time and money; Section 4.6 will deal with reuse in more detail.

New data are created in different ways in different fields of research. The collection of survey data in the social sciences, for instance, differs fundamentally from the collection of the many terabytes of data generated by the experiments performed with the LOFAR telescope in Exloo.[8] To ensure that data remain usable in the later phases of the cycle – and that the data can easily transition from one phase to the next – several aspects must be considered during the first phase of creation.

- For research involving personal data, as in medical information, it is necessary to obtain informed consent to the subsequent processing of the data.[9] If researchers neglect to do this prior to the collection of the data, the data may prove to be unusable later on. An alternative may be to process the data so that tracing them to individual subjects is no longer reasonably possible. For research involving large amounts of (aggregated) data, this may not be an issue, but in other cases, anonymising data means destroying some of their value. These issues should be carefully considered as early as when preparing a research proposal. Similar considerations may apply to research involving data that are commercially or militarily sensitive, for instance.
- Restrictions may also apply to research performed in collaboration with private parties. Commercial interests or patents could prevent data from being made accessible and reusable straight away. Documenting restrictions of this nature ahead of time can be done, for instance, using a Consortium Agreement (in the case of projects financed by the European Union).
- Researchers should attach correct and consistent metadata to their data from the beginning, to allow the data to remain intelligible in later phases.
- More 'technical' issues include the choice of file formats (for the importance of this choice, see the 'Reusing data' phase), naming conventions, and the organisation of the folder structure. For example, using '151016' in a file name as an indication of the date is ambiguous:

8 For more examples of data creation, see http://datasupport.researchdata.nl/en/start-de-cursus/iii-onderzoeksfase/data-verzamelen/.
9 The UK Data Archive provides additional information as well as various templates related to this topic. See http://www.data-archive.ac.uk/create-manage/consent-ethics/consent?index=3.

it could refer to either the 15th of October, 2016, or the 16th of October, 2015. A better choice would be to use a standardised form of notation, such as YYYY-MM-DD: 20161015 for the 15th of October, 2016. For explicit agreements within a project team about folder structure and file names, the term 'data organisation' is also used.

4.2 'Processing data' phase

The processing phase is home to activities like translating, validating, anonymising, and cleaning data – by removing statistical outliers, for example (documented, of course!) – as well as the further description and documentation of the data. These activities are performed on raw data, with processed data as the result. This phase, too, differs profoundly between disciplines: in some cases, several subsequent rounds of processing are required, in which case every intermediate version will need to be saved so that every step of the process can be retraced, while in very data-intensive fields, such as particle physics, an automated process will lead to an initial reduction of the amount of data, with the subsequent remainder being considered raw data.

A crucial, generic activity is the storage of data during the course of the research project (see Section 4.4 for keeping data once the project has concluded, also called preservation or archiving). Here, too, close attention should be paid to those aspects enabling data to proceed through the cycle. Regulations, codes of conduct (national, institutional, or legal), and existing agreements often play an important role. One example is the physical storage facility's geographical location: universities on occasion do not permit data to be stored off-campus, while in other cases, data may be restricted to a location within Europe. It must be possible, technically, to migrate the stored data to an archive in a later phase; an offline storage site using an exotic operating system may make this difficult. For storage in general, several best practices can be listed:[10]

- Save your data in an open, standard format that is not bound to a specific software provider, to allow for reuse and future conversion of the data by an archive.
- Even for short-term projects, implement a data storage strategy using two different types of storage medium, such as CDs and hard disks. Being dependent on a single medium causes risks when this medium (or the necessary software) becomes corrupt or outdated.
- Copy or migrate the data to new storage media every two to five years. The quality of storage media deteriorates over time, and at a certain point they will prove unusable by the then-current hardware and software.
- Do not overwrite an old backup with a new backup. It is better to create an entirely new backup copy of files that have been changed, so you can always go 'back in time' to a specific version.
- Calculate a checksum for your data, and regularly verify the integrity of the data using a checksum checker. This way, you can make sure you are still working with the same version. If a bit 'falls over', this will result in a different checksum; an earlier version of the data should

10 http://datasupport.researchdata.nl/en/start-de-cursus/iii-onderzoeksfase/data-opslaan/.

then be reloaded to ascertain exactly what went wrong.

The number of online applications that can be used in service of these goals is vast. These services are provided by private parties, like Mendeley, Figshare and Dropbox, but also by non-profit organisations: in the Netherlands, for instance, SURF offers Beehub and SURFdrive, while DANS hosts DataverseNL. Naturally, the functionality of these storage services will vary. An institution's (policy) framework must also be considered in choosing a storage system: sometimes there are pre-existing contracts with service providers; conversely, the use of a particular service may be prohibited. An institution may also prefer a system that is already in use within an international collaborative framework of which it is a part, or may have set certain minimal security conditions.

During the processing phase, as well as the following analysis phase, researchers will make use of certain protocols, software, and tools. Transparency must also be upheld regarding these tools and how they have been used. How have statistical outliers been removed, for instance? How have interview statements been encoded, that is, sorted into categories: by a machine, one or more assistants, or the researcher him- or herself? In ideal cases, the researcher can refer to standard methods and tools within their field in documenting his or her work.

4.3 'Analysing data' phase

Once the data has been properly processed, interpretation and analysis can take place. In this phase, visualisations are generated based on the data, and articles and other scientific output are produced. For many researchers, this is the crux of the research process: when they use the data to test their hypothesis, or in research not involving a hypothesis, when they uncover certain patterns in the data. Data management in this phase is defined by proper documentation of each step of the analysis process and verification of its execution, as the Netherlands Code of Conduct for Academic Practice (VSNU, 2014) prescribes, under the header of verifiability. The connection between (raw) research data and a scientific article must be a transparent process: it should be clear to other researchers how the data support the conclusion, and what was done with the data to reach that conclusion. In this phase, too, the protocols, software, and tools that have been used must be documented to guarantee the reusability of the data. Documentation of this nature is usually included in scientific publications, but not always with the degree of detail necessary for replication. For instance, the Code of Conduct also mentions documentation of arrangements and decisions (VSNU, 2014, p. 8). Depending on the standards and conventions within a particular field, an extensive description may be needed, or a reference to the relevant standard may suffice. The four data levels used in particle physics,[11] for example, are well-known within that community, and will not require an extensive explanation.

11 As an example, see the four levels of data preservation listed in https://www.dphep.org/sites/site_dphep/content/e36435/e67191/e221646/chep13validationPoster.pdf.

4.4 'Preserving data' phase

As mentioned in chapter 3, it is prudent to differentiate between the management of data during research ('storage') and the long-term management of data after research has ended ('Preserving' or 'preservation'). In moving from the analysis phase to the preservation phase, a researcher has reached the latter of these two stages. At this point, different agreements may need to be reached about who has access to the data and/or who is responsible for maintaining and managing the data. The term 'preservation' also covers such activities as are needed to prevent data from becoming outdated, and hence unusable. In other words, the preserving data phase is concerned with activities aimed at achieving digital sustainability.

Digital preservation

"Sustained access is about keeping digital and digitised heritage material accessible in the long term. The digital world is characterised by rapid technological change. Hardware and software quickly become outdated. Who still has a floppy disk drive these days? And yet many digital objects have been stored using this medium in the past. This means that it's important, right from the start, to think about the form in which you want to preserve your digital data for the future."[12] This appeal by the DEN Foundation applies to research data as well. DEN, along with the National Library (KB), National Archive, DANS, and the Netherlands Institute for Sound and Vision, is a member of the Netherlands Coalition for Digital Preservation (NCDD).[13] This umbrella organisation collects information for its members and carries out projects within the national Digital Heritage Network.

One of the NCDD's projects is aimed at the certification of repositories. Within the research sector, especially, there is already a great deal of experience in this area. Most data archives that carry the Data Seal of Approval[14] or are a member of ICSU World Data System[15] carry out long-term preservation of their research data. To earn the Data Seal of Approval (DSA), for instance, the archive must show that:

- the data can be found on the Internet;
- the data are accessible (with clear rights and licences);
- the data are in a usable format;
- the data are reliable;
- the data are identified in a unique and persistent way so that they can be referred to.

Not coincidentally, the DSA's repository criteria have significant overlap with the FAIR data principles. For more information on so-called Trustworthy Digital Repositories and the DSA, we refer the reader to Dillo and De Leeuw (2015).

Although few sustainable repositories for software are available as of

12 http://www.den.nl/thema/16/ (in Dutch).
13 http://www.ncdd.nl/.
14 http://www.datasealofapproval.org/.
15 https://www.icsu-wds.org/community/membership.

yet, there is a broad awareness of the fact that software sustainability is also an important part of data management and digital preservation. An increasing amount of data is dependent on software for their interpretation. Software in GitHub can be easily archived in CERN's Zenodo archive.[16] This archive will keep the software code accessible for a long period of time, but there is currently no policy for further preservation. In the Netherlands, the NCDD, KB, Netherlands eScience Center, and DANS collaborate in building knowledge, services, and support; DANS has also entered into an alliance with the French Inria for the further development of the Software Heritage initiative.[17]

In the interest of FAIR data, researchers are advised to deposit their data, along with all the documentation needed to make sure they can be reused, in a research data archive with both the explicit goal and the necessary expertise to store data sustainably and maintain their usability. Research institutions often also provide access to their own server for archiving, but they usually lack specific expertise, as long-term preservation and access are not among those institutions' primary tasks. Research funders like the European Commission frequently express a preference for certified data archives, but these do not yet exist for every field. NWO states: "The data should preferably be stored for the long term in a national or international data repository. If this is not possible then the data should be stored by the institutional repository." The guidance about the DMP (NWO, 2016) refers, among other things, to DSA's sustainability guidelines.

If no national, domain-specific or institutional archives are available, a generic solution, like Zenodo, may also be used. The Registry of Research Data Repositories (re3data.org) is a global registry of data repositories. For each repository, this registry includes information on certification (if any), persistent identifiers, licences, and access categories, and can easily be searched and sorted by country, discipline, or type of data.[18] Archives like Dryad[19] and DANS EASY[20] offer advice and instructions for preparing data for archiving – in a much earlier phase of the research cycle. Accordingly, it pays to get in touch ahead of time with an archive that has the required expertise in one's field and/or experience with the specific type of data one is using, such as survey or sensor data.

To guarantee the future reusability of data, data archives recommend that researchers select so-called sustainable formats: file formats that are widely used, have open specifications, and are not dependent on specific providers or software. Files in one of these formats can eventually be converted by the data archive to the next generation of sustainable formats, meaning the data will remain usable. Whether an archive regards certain file formats as sustainable or not will depend on the target audience – scientific disciplines may have their own specific preferences –

16 https://zenodo.org/.
17 https://www.softwareheritage.org/mission/.
18 http://re3data.org.
19 https://datadryad.org/pages/faq.
20 https://dans.knaw.nl/en/deposit/information-about-depositing-data?set_language=en.

and expertise of the archive in question; see, for example, the information listed by 4TU.ResearchData[21] and DANS[22] regarding their preferred data formats.

There are a number of facts that depositors should determine or be aware of when they transition from the analysis phase to the preservation phase:

- Does the archive accept my file formats, or should the data be converted to a different format to ensure their sustained usability?
- What metadata are attached to my data? Do they provide enough information for third parties to find the data and get an impression of their relevance and usability? If a discipline-specific metadata standard exists or is required, has it in fact been used?
- Is the documentation complete and in suitable file formats, so a visitor to the archive and potential user of my data can interpret them in their proper context?
- Does the archive support my desired access category: Open or Restricted Access (or gradations of the same)?
- Who gets access to my data? Have any conditions and limitations, such as ‘we will charge you for selecting these data’ or ‘for researchers only’, been clearly formulated? If the data are not Open Access, is it apparent how interested parties can apply for access to the data?
- Does the archive assign a persistent identifier like the Digital Object Identifier (DOI) to my data, allowing users to cite these data correctly, as is the academic rule for the citation of publications and books?[23]

Many archives formalise the deposition of data at the moment of transfer using a deposit licence. With this licence, the depositor attests that he or she holds the rights to the data, or acts with the permission of the rights holder. The licence will state, for example, that the depositor may also make his or her data accessible at another location, while the archive has the right and the responsibility to convert the data to a new file format before they becomes unusable. It may also include provisions stipulating what the archive will do when an embargo period has ended, when the depositor has died, or when the depositing institution has been closed.[24]

4.5 ‘Giving access to data’ phase

At this stage, giving access to data means making sure that you make the data available to outsiders: people not involved with your research. *Findable* and *accessible* are the primary FAIR principles to consider in this phase. Archives like the Australian National Data Service (ANDS) consider the data to be ‘published’ when they have reached this phase: “This domain involves the public sphere (publication in the sense of making

21 http://researchdata.4tu.nl/en/publishing-research/data-description-and-formats/.
22 https://dans.knaw.nl/en/deposit/information-about-depositing-data/DANSpreferredformatsUK.pdf.
23 A persistent identifier (PID) is a unique identification code attached to a digital object, which is registered at an agreed-upon location. It is guaranteed to remain functional, even if an organisation’s web address changes. For information on DOIs and other PIDs – in Dutch –, see the dossier at http://www.ncdd.nl/pid/.
24 See, for example, https://dans.knaw.nl/en/about/organisation-and-policy/legal-information?set_language=en.

public)".[25] The data, along with the associated metadata and other required documentation, have now been deposited in an external archive or stored in the research institution's own repository. Incidentally, the term 'public' in this context does not necessarily imply that all the data are openly accessible to anyone, any more than this would be the case for every publication in a scientific journal.

In ideal cases, the data will be openly accessible and properly documented; if so, this phase will require little more attention. In practice, however, there are usually some factors to consider, many of which relate to some of the activities performed in earlier phases. It must, for example, be clear exactly who is allowed to do what with these data, and this may depend in part on informed consent, as well as any contracts with project partners and/or third parties; see Section 4.1. To this end, a user licence can be used, like one of the Creative Commons licences,[26] which come in several versions with varying levels of restrictiveness. It is important to attach a licence even to open data, for two reasons:[27] firstly, this will explicitly record the open nature of these data; secondly, this will allow the original rights holder to include a clause, if he or she wishes, stipulating that any new data derived from these data must also be made openly accessible. This principle, known as 'share alike', can also be implemented for data that are not allowed to be used for commercial purposes; in this case, the same restriction will apply to so-called downstream use (meaning the next round of reuse). A user licence may also stipulate that users are bound by copyright and database law, by academic standards concerning, for instance, correct scientific citation, and by the Wet Bescherming Persoonsgegevens (WBP, or Protection of Personal Information Act) – the latter is relevant if data can be traced to individual subjects.[28] User licences are often provided by the archive, and are drafted along with the deposit licence (see Section 4.4).

We not only recommend that researchers make the choice between Open and Restricted Access at an early stage, but also that if Restricted Access is chosen, the precise terms of access be made clear. Does the researcher or research group holding the rights to the data want to be credited as co-author for publications based on their data, or will users be charged for selecting these data from a larger collection? What information – research question and methodology, for example – should an interested party submit in a request for access, and who decides on these requests: the original researcher (not a very sustainable approach), his or her institution, or the data archive (which does not necessarily possess any substantive information regarding the data's contents)?

One final aspect of this phase in the data life cycle is mentioned by the UK Data Archive: promoting data. Archived data will be findable through the

25 http://www.ands.org.au/guides/curation-continuum.
26 https://creativecommons.org/.
27 For open software and their documentation, GNU licences may apply; see https://www.gnu.org/licenses/licenses.html.
28 VSNU Code of Conduct for the Use of Personal Data in Scientific Research – in Dutch, http://vsnu.nl/code-pers-gegevens.html; Wet Bescherming Persoonsgegevens, http://wetten.overheid.nl/BWBR0011468/2016-01-01.

data archive's catalogue, and the archive will also (automatically) make the metadata available to search portals or discovery services like NARCIS,[29] DataCite,[30] OpenAIRE,[31] and B2FIND;[32] this may not be the case for institutional repositories. Beyond that, the individual researcher, his or her institution, the project team, and funders may work to promote the available data to potential users. It is crucial, in this context, to use the persistent identifier attached to the data by the archive, as that alone forms a reliable, sustainable link that can be used for citations.

4.6 'Reusing data' phase

The reuse of data is a key goal of the entire data life cycle. Good management of storage and archiving, documentation, and data formats will have made the data suitable for verification, follow-up and/or entirely new, original research. The degree of reuse, and the conventions and standards surrounding it, may differ from field to field, depending on the measure of 'data intensity' inherent to each. In one research group, the convention might be for PhD students to build on the data collections of their predecessors or colleagues; in another field, where researchers generally work alone or in small teams, data might more often be collected or generated individually. The degree to which tools, software, models, or methods are reused will also vary widely. Whenever a discipline or department establishes agreements regarding the treatment of data, potentially including the reuse of data, it is prudent to make sure these agreements match up well with one's own workflow and mores; see Aerts and Doorn (2016), as well as the section on data policy in Section 5.1.

Aside from reuse in new research projects, scientists can also describe and review a data set in a so-called data paper. Furthermore, available research data may be used for educational purposes.[33] Depending on access rights, third parties could also make use of your data: citizens (in what is known as citizen science), public sector institutions, and businesses.

The potential for reuse of data in this phase is largely determined by the activities performed in the earlier phases, described above. These include:

- The choice of an archive: since the archive making the data available to others is largely responsible for the degree of reusability (consider the access rights it may implement, or its support for certain, domain-specific metadata), this initial choice is of the utmost importance. Criteria and tools researchers can use to make this choice have been listed in Section 4.4. This does, however, assume that the researcher or depositor is already aware of these tools (see Section 5.2.).
- Documentation and metadata: the quality of the descriptive

29 NARCIS provides access to scientific information within the Netherlands; see http://www.narcis.nl.
30 http://search.datacite.org/.
31 https://www.openaire.eu/.
32 http://b2find.eudat.eu/.
33 A remarkable example of data suitable for reuse in an educational context – in Dutch – can be found in the various data sets published by Statistics Netherlands at https://www.cbs.nl/nl-nl/onze-diensten/in-de-klas.

information regarding the data has a profound impact on their intelligibility. If the metadata and documentation do not enable users to determine how the data were generated, what the meaning of certain variables is, etc., it will be much harder for them to decide whether they can use these data. Making the corresponding software, scripts, and methodology available will also make it easier to tell how the data may be used. In short: the more documentation of the data's context, the better.

- File formats: the chosen file formats will determine which software can be used to work with these data. Choosing software with open standards, such as OpenDocument Text (.odt) instead of Word© (.docx), will make reuse less dependent on a specific software package. The open nature of these formats (as opposed to so-called proprietary formats by Microsoft or other companies) also means that it is possible to develop new software that uses these same formats. For this reason, Trustworthy Digital Repositories often publish their data in these open, sustainable file formats (see Section 4.4).
- Access rights: perhaps the most important aspect to consider in terms of reusability are the rights users have to a given data set. If it was decided in an earlier phase that the data will not be openly accessible for reuse, then reuse will simply not be possible! There are good reasons why research funders and policy makers encourage researchers to make their data completely and openly accessible, although they acknowledge that this may not always be possible. The motto is: 'open if possible, restricted if necessary'.

5. Data roles, policy, and stakeholders in the Netherlands

5.1 Stakeholders

In the previous chapter, we have discussed the various phases of the research data life cycle, referring at times to the different stakeholders that play a role in the data management process: researchers, funders, archives, etc. This chapter will examine these different roles and the corresponding responsibilities in more detail.

Stakeholders in data management and their responsibilities

The various stakeholders have and, in some cases, share responsibility for several aspects of data management:[34]

- The principal investigator – responsible for the data and data management; has primary responsibility for the DMP, unless otherwise agreed upon with the project leader;
- Other researchers, research assistants, and/or data managers – involved in the practical day-to-day management of data;
- Senior researchers and research coordinators – exemplary behaviour, mentorship, and supervision of (young) researchers;
- Management and/or board of the research institution – drafting and monitoring of data policy; encouraging data awareness among all practitioners of science;
- Front office of the research institution, including library, IT, and legal staff – providing access to external data and tools, secure storage, and data; legal and ethical expertise, data citation, metadata, access and licences, finance conditions; encouraging data awareness (also see Section 5.2);
- Research funders – encouraging good data management; encouraging data awareness; investing in data infrastructure;
- Project partners at research institutions and businesses – see 'other researchers';
- Scientific publishers – setting data accessibility conditions with regard to submitted and/or published articles; attaching persistent identifiers to publications, and referring to the associated data;
- Archives and repositories for research data – providing long-term access to the data; attaching persistent identifiers; making data findable (data discovery service);
- Data users, including researchers, government, journalists, businesses, citizen scientists, teachers, and students – using and disseminating data in accordance with their access rights and licences; citing used data in a scientifically correct manner.

Although it is possible, in theory, for data management to be performed by a single organisation throughout the entirety of the data life cycle, experience has shown that a more efficient approach is to have the different phases be carried out by different organisations or institutions – after all, a single group cannot specialise in everything, or have the activities of every phase as part of its mission statement. Accordingly, an environment has been developed within the Netherlands in which various

34 This list is partially based on (OpenAIRE, 2015).

organisations collaborate in the interest of high-quality data management. Generic services for long-term archiving, the creation of persistent identifiers for data sets, and training for support staff are all carried out by central organisations like Research Data Netherlands (RDNL),[35] the collaborative framework of university libraries and the National Library (UKB), and SURF.

Also outside the aforementioned framework, the Dutch university libraries (and, increasingly, the libraries of other higher education institutions) often play a part in this process (see Section 5.2 for the activities performed by these libraries). In the RDNL Front Office/Back Office model, university libraries are considered front offices: they are in direct contact with researchers, and by offering advice, they can ensure that research data is deposited in one of the RDNL archives (the back office).[36] The library's employees provide guidance to the researchers working at research institutions, so they can meet the standards set by law, funders, their own institution, or a journal they wish to submit their work to. Collaboration, the exchange of knowledge, and the sharing of best practices take place, among other places, at the UKB's Research Data Working Group.[37] The Working Group has translated the UKDA life cycle model into three phases: at the start of, during, and after research. It has identified the activities in each phase for which the university library can provide support.[38]

The National Coordination Point Research Data Management (LCRDM), founded in 2015, works to facilitate a nationwide approach to research data management in the Netherlands. At the request of VSNU, the umbrella organisation for Dutch universities, SURFsara – as part of the Sustainable Data innovation programme[39] – is coordinating this process, in collaboration with Dutch education and research institutions, the RDNL partners, the Research Data special interest group,[40] and the UKB Research Data Working Group. They have identified five essential themes, which are being worked out in national working groups: facilities and data infrastructure; legal aspects and accountability; finance; research support and advice; and raising awareness of the benefits of RDM. The goal is for data management to become a matter of course in both the policies and the practices of Dutch universities and research institutions. Crucial goals to realise include: synergy between policy, IT, and research support; connection between experts at research organisations, facilitating organisations, and research funders; and the embedding of data (management) policy in institutional administration.

35 http://www.researchdata.nl/en/.
36 A list of front offices at Dutch universities can be found at https://www1.edugroepen.nl/sites/RDM_platform/Lists/RDM bij universiteiten in Nederland/AllItems.aspx.
37 https://www.ukb.nl/research-data – in Dutch.
38 See https://www.ukb.nl/sites/ukb/files/docs/Opdracht-wg-ukd-data-2015.pdf - in Dutch.
39 https://www.surf.nl/en/innovationprojects/sustainable-data.html.
40 https://www.surfspace.nl/sig/28-research-data/29-over-de-sig/ - in Dutch.

Data policy

The topics listed below have been extracted from the data (management) policies of nearly twenty organisations within the Netherlands and abroad. Data policy, too, is a theme with many variations: three pages may suffice for some institutions, while for others, data policy documents may be dozens of pages long. Most institutions agree, however, that the policy framework should be established at the level of the Executive Board or Board of Directors, and that the responsibility for concretisation and execution of this policy should be delegated to lower levels, such as faculties or research schools (see (Aerts and Doorn, 2016) for an argument in favour of creating discipline-specific protocols).

We have roughly sorted the large number of topics included in these policy documents into groups. Naturally, other groupings could have been used instead, and additional topics could yet be added to the list, but this 'long list' will serve as a solid foundation for a discussion of what can or should be covered in an institution's data policy.

Goals

1. The goal of the data (management) policy; ensuring the replicability or verifiability of research, for instance, or increasing the visibility of the institution's research results.
2. The administrator's and/or the organisation's vision on data, data policy, and/or data management.
3. Open access to publications and data – 'open if possible, restricted if necessary'; handling sensitive data; encoding data; interoperability and changeability of file formats; implementing an embargo period if necessary.
4. Encouraging and maintaining trust in science, within the institution and among third parties, by archiving data in certified Trustworthy Digital Repositories whenever possible, for example.

Data quality

1. The provenance (have the data been purchased from an external data provider? How were they collected? How were they processed during research?) and reliability of data; FAIR principles; metadata.
2. Minimal codes of conduct; the scientific context; relevant laws and regulations within and outside of the institutions; academic norms; the role of an ethics committee, if applicable.

Means

1. Data ownership, including conditions for the reuse of data generated by the institutions, review of the data by a non-regular entity, such as a journal reviewer or integrity committee; how to cite one's own and other people's data; agreements concerning contract research.
2. Data storage during research and archiving afterwards: securing data before researchers leave; safe storage, backup, and version control; using a replication package (everything you need to replicate a given study) as the archiving unit; minimum and/or maximum storage periods; are there any selection criteria? Can or

should any data be destroyed? Also see the points under ‘Data quality’.
3. Supporting researchers through training, data managers, assistance in writing DMPs, and ‘tutoring’ young researchers.
4. Financing the technical and human infrastructure for data management, including many of the topics in this list.

Responsibility and accountability
1. Enhancing the visibility and acknowledgement of both researchers and, for example, software developers and data supporters; citing data correctly; encouraging the use of a data citation index as a counterpart to the h-index for publications.
2. Including compliance with this data policy in development or appraisal interviews (“Where did you archive the data connected to this publication?”); other forms of supervision, like internal audits
3. Budgeting the costs of data management in project or department plans; tracking the costs at one or more levels of the organisation; also see the final point under ‘Means’.
4. The responsibilities with regard to data held by the researcher, supervisor, institution, and other stakeholders.
5. Periodic evaluations of this data policy at multiple levels of the organisation.

5.2 Institutional data management support

What is understood by data management support varies widely between institutions and remains in a state of flux.[41] This diversity is also expressed in the nomenclature: the responsible employees are variously termed ‘data librarian’, ‘data steward’ or ‘RDM support’. Nevertheless, the activities performed by these employees, who are largely positioned in university libraries, are certainly comparable. They are connected to existing activities and expertise at these libraries: the description/metadating of data, access control, and finding and reusing data. In many cases, libraries collaborate with the university’s IT support team. Additional expertise is gained in the available courses, like ‘Essentials 4 Data Support’,[42] and in the aforementioned collaborative frameworks, such as UKB, LCRDM, and SURF.

A quick tour of the pages about RDM on the websites of Dutch universities will demonstrate that the university libraries provide support for the entire research data life cycle: from assistance in writing a DMP to mediating between researchers and long-term archives. The section below lists the various activities performed in each phase. Other activities, not bound to any specific phase of the cycle, include: training researchers and support staff, providing discipline-specific contacts and support, and offering generically useful information about RDM (checklists, lists of terms, FAQs, links), illustrated with good practices that have been implemented at that

41 Henceforth we will simply refer to ‘university libraries’, since RDM support is provided at every Dutch university. The attention being paid to research data is also increasing at the universities of applied sciences (in Dutch: hogescholen), but support services are currently less common there.
42 http://datasupport.researchdata.nl/nl/.

institution.

A good example of the support provided to researchers – and also of the aforementioned Front Office/Back Office model – is the service offered by Radboud University: their local RDM system (called 'Research Information Services') allows researchers to simultaneously register and store their publications and data sets (Simons et al., 2016). This system is linked to DANS's long-term archive, EASY. The staff at Radboud University offer assistance in using RIS and making sure that the data sets in the local university system meet the preservation standards set by EASY. This means that researchers need to use only a single system to meet the demands set by their institution as well as by the funder.

Activities by research cycle phase

The list below was compiled by collecting the activities mentioned on university library websites as part of their data management support services. We have sorted them into categories based on the different phases of the research data life cycle.

'Creating data' phase:

- Providing assistance in writing data management plans and project proposals / grant submissions
- Providing templates for data management plans
- Providing information and advice on grant provisions and data-related demands set by funders (NWO, ZonMw, Horizon2020)
- Providing information and advice on institutional data policy and codes of conduct
- Providing support in searching for existing data, or referring to systems and search engines (such as NARCIS, DataCite, and B2Find)
- Providing support and advice on legal and ethical matters (such as WBP, or the risk qualification of data) and data anonymisation
- Providing advice on the costs of data management, and how to budget for it in a project proposal

'Processing data' phase:

- Providing (data) lab environments and Virtual Research Environments (VREs)
- Providing local storage or repository systems to save and share data during research (such as DataverseNL, Beehub, SURFdrive, Figshare, or SharePoint)
- Providing software management systems
- Providing advice on (technical) data security
- Referring to discipline-specific storage solutions
- Providing persistent identifier services (such as Handle or DOI)
- Providing advice on temporary storage
    - Providing advice on metadating and standards
    - Providing assistance in documenting data

'Analysing data' phase:

- Providing visualisation tools and infrastructure
- Providing computational services (on campus or at SURFsara, for instance)

- Providing or listing relevant software (such as lab journals)
- Providing assistance in documenting data

‘Preserving data’ phase:
- Providing advice on sustainable archiving
- Providing a Trustworthy Digital Repository (currently just 4TU.ResearchData)
- Referring or linking to a national or international TDR
- Providing persistent identifier services (such as Handle or DOI)
- Archiving non-digital data

‘Giving access to data’ phase:
- Providing advice on access, both Open and Restricted, and embargo periods, if applicable
- Registering data sets in a local CRIS system
- Providing information and advice on funders’ and publishers’ demands
- Providing information and advice on licences
- Referring to relevant data journals

‘Reusing data’ phase:
- Providing search engines (locally, NARCIS, etc.)
- Providing information and advice on data citation
- Offering course modules to research master and PhD students

In the RDM activities performed at these institutions, a great deal of attention is paid to the reasons for good data management, coupled with an explanation of the university’s data management policy, if there is one. Enhancing understanding among researchers of the nature of good RDM is a crucial goal. To this end, data management courses, workshops, and training are offered to researchers and information service staff.

By increasing awareness of research data management – across the board: from funders, to researchers, to support staff – we can ensure that research data is handled properly, in present and in future. More data will be available for reuse, and more data will be reused. In the end, reuse of any form will help contribute to the solutions, mentioned in chapter 2, to “today’s grand challenges, such as climate change and energy supply”.

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This white paper offers an overview of the current state of affairs of research data management in the Netherlands. The text looks at national developments in higher education and science, using the various phases of the research cycle as a framework. Key terms are defined and special attention is given to the role of data support staff. By its very nature, this overview can never be exhaustive. Research data management is in a constant state of flux, both nationally and internationally, and new data services are regularly being introduced. At the same time, it is precisely this dynamism which calls for an overview of this kind.

This document is a translation of a chapter in Handboek Informatiewetenschap (www.iwabase.nl) on research data management. This chapter was written by Marnix van Berchum (Huygens ING) and Marjan Grootveld (DANS).

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