Data Management Plan in Research: Characteristics and Development

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Abstract. Data science is an interdisciplinary field that extracts value from data. One of the relevant areas is its application in research in order to define requirements of the data life cycle. Thus, data should be managed before, during, and after a research project completion. A robust data management plan (DMP) is a relevant and useful instrument to establish data-related requirements. In this context, this paper aims at highlighting some characteristics associated to research data management. To conduct this study peer-reviewed literature and secondary data are methodologically employed to fulfil the paper objective. The results discuss the development of DMP, provide some examples of documents and a check list related to data management, and present some recommendations for developing a suitable data management plan from the literature. The data management plan is one of the important instruments that should be considered with care when designing and applying it. Future work may consider providing a structure and guidance for research students in the field of industrial engineering as a valuable avenue to explore.

Keywords: Data planning · Research plan · Research Data Management

1 Introduction

Data science is a broad and an interdisciplinary domain present in various subjects, such as computing, statistics, biology, engineering, and many others. One of the relevant areas is associated to managing data in research in order to specify data requirements from data discovery/collection to dissemination and data conservation [1].

Although researchers usually establish and record data collection and analysis procedures, it is not so usual to address with the same extent of detail other stages of the data life cycle particularly in the field of industrial engineering. To this end, a robust data management plan (DMP) is a relevant and useful instrument to establish data-related requirements. DMP provides structured data-related contents during and after a completion of a research project [1]. Indeed, data management has been a critical skill for researchers [2, 3]. Moreover, in recent years most of funding agencies (e.g. in Europe and

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in the US) require that data management plans must be submitted as part of a research proposition [1, 3].

In this context, the aim of this paper is to highlight some characteristics with regard to data management for research. Another potential outcome of this study is the knowledge of specificities related to data management plan that might help beginners when starting to deal with this kind of instrument.

The remainder of this paper is structured as follows. Section 2 briefly outlines some concepts that support the study development. Section 3 describes the research procedures while Sect. 4 outlines the outcomes and discussion related to the scope of this work. Finally, Sect. 5 draws some concluding remarks from this work.

2 Brief Literature Background on Data Management

Data can be defined as "everything that would be needed to reproduce a given scientific output" [4]. Research data management (RDM) could be described as the process that requires one to create, organize, keep, find, and share data [5]. Data management guarantees that the process used by the researcher to the collection is organized, clear, and understandable [4], aiming to support the research process reproducibility. Data is exposed to risks during the lifecycle of a research project, and it can affect their fair use and interpretation; therefore, data management helps to ensure its availability [6]. Proper data management also becomes necessary to strengthen open science by sharing accurate data [7].

There are many visualizations of RDM as a lifecycle, although no consensus exists [5]. Data management lifecycle encompasses [4]: (i) creating or collecting data; (ii) processing data; (iii) analysing the data; (iv) preserving data; (v) providing access to data; and (vi) reusing the data to conduct new studies. New RDM lifecycle visualizations could be helpful to stakeholders to understand their tasks and responsibilities as well as to explain the logic and order of activities in the research process [5].

Researchers still need guidance on practices that could facilitate data usage and understanding of specialized concepts, for instance, metadata and policies for data use and reuse [8]. Therefore, RDM is still a challenge for researchers and research institutions, that is amplified with the growing role that digital disruption plays in research activities and in the variety of tools available [9]. According to Mannheimer [8], most researchers practice internal data management to prevent losing data, to maintain a constant workflow even with researchers' turnover, and to make sharing within the team easier.

A data management plan is a written description document detailing how a researcher plans to collect, store, describe, preserve, and make data available [10]. The DMP goes through peer review and can be used in part to evaluate a research project merit [1]. Michener [1] adds that plans also help to document data management activities related to funded projects that may be re-examined throughout performance reviews. DMP could vary in length from a short document (from 1 to 2 pages) constructed by the primary investigator to a multi-page report prepared within the frame of a research project to direct the team through all aspects of the research data management [11].

After the US National Science Foundation announced that all funding proposals from 2011 onward must include a DMP, the interest in the topic has grown exponentially

[10, 12]. Other federal funding agencies, such as the National Aeronautics and Space Administration, require DMP and many others are going to require shortly [13]. In the 2014–16 work programme of Horizon 2020, the Open Research Data Pilot (ORD pilot) was included in selected areas; in 2017, the revised version extended ORD pilot to all thematic areas [14]. Many European universities are supporting open scholarship and science and initiatives in the field of open data [15].

Publishers are also encouraging researchers to use RDM. For instance, Elsevier [16] provides free access e-learning resources to support researchers on managing and publishing research data, as well as creating a DMP and benefiting from citing data. Besides, Research Data Management Librarian Academy – RDMLA [17] is a group of university libraries partnering with Elsevier to provide online RDM training.

No unique formula for appropriate data management exists, as the task depends on the science domain, the types of data, and the size of the project [7]. Nevertheless, a DMP normally includes [11]: (i) data that will be created; (ii) data documentation and organization; (iii) data storage and security; (iv) data management and preservation after project completion; and (v) data accessibility for reuse and sharing. Experience and knowledge gained in developing DMP will be valuable over the next years [15].

Van der Loon *et al.* [13] compare DMP from different areas and academic units and highlight that shortcomings vary across them. Many DMP analysed by the authors provides an ambiguous or insufficient description of how research data will be managed, preserved, and shared. The authors also point out that engineering researchers rarely mention data sharing through supplemental material enclosed in journal articles.

There are several tools available to help researchers develop the skills needed to make choices and guide users to create data management plans [10]. Some outlets analysed the usage of some of them, such as: ERDMAS [9], MANTRA [10], DMP tool [11, 12], and DMP online and IEDA Data Management Plan Tool [12].

Reilly and Dryden [12] recommend that each institution should build its own tool to comprise specific local information concerning their researcher funding activities, including resources, services available on campus, particular policies, and requirements. Therefore, there is a need that research agencies get engaged with distinct scientific communities to develop data management plan formats that best suit specific disciplines [7]. RDM service providers also need to build the expertise to address the needs of individual researchers or research groups [15].

2.1 FAIR Data Principles

DMP requirements from funding agencies are generally committed with standards like the FAIR Data Principles [8]. For instance, European Commission Horizon 2020 FAIR DMP [14] provides such requirements. In general terms, FAIR data principles [18] states that data must be structured to be “Findable”, “Accessible”, “Interoperable”, and “Reusable”. Figure 1 illustrates FAIR guiding principles.

2.2 Data Life Cycle in Research

Figure 2 depicts the relationship between hypothetical research and data life cycle. As can be seen in Fig. 2, there are a number of stages in which data is present before, during,

To be **F**indable	F1. (meta)data are assigned a globally unique and persistent identifier F2. data are described with rich metadata (defined by R1 below) F3. metadata clearly and explicitly include the identifier of the data it describes F4. (meta)data are registered or indexed in a searchable resource
To be **A**ccessible	A1. (meta)data are retrievable by their identifier using a standardized communications protocol A1.1 the protocol is open, free, and universally implementable A1.2 the protocol allows for an authentication and authorization procedure, where necessary A2. metadata are accessible, even when the data are no longer available
To be **I**nteroperable	I1. (meta)data use a formal, accessible, shared, and broadly applicable language for knowledge representation I2. (meta)data use vocabularies that follow FAIR principles I3. (meta)data include qualified references to other (meta)data
To be **R**eusable	R1. meta(data) are richly described with a plurality of accurate and relevant attributes R1.1. (meta)data are released with a clear and accessible data usage license R1.2. (meta)data are associated with detailed provenance R1.3. (meta)data meet domain-relevant community standards

Fig. 1. FAIR guiding principles [18].

and after finishing a research project. The circles with numbers mean details that are linked to the data life stages. The researchers usually: (1) test hypotheses; (2) collect data; (3) interpret data; (4) disseminate by publishing. Considering the data life stages at 'B', researchers normally: (1) develop a data plan; (2) discover/collect and (3) organize data; (4) ensure data quality; (5) describe and (6) analyse the data; and (7) preserve and (8) share the data with other researchers.

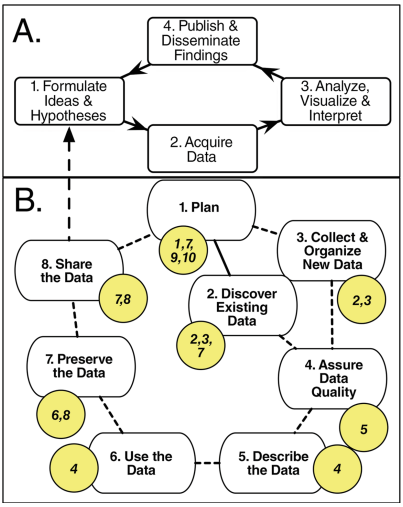

Fig. 2. Research stages (A) and the data management stages (B) [1].

A data plan should cover all or portions of the data life cycle [1]: from data discovery, collection, and organization (e.g., spreadsheets, databases), through quality assurance and control, documentation (e.g., data types, research methods and others) and data usage, to data preservation and sharing with others (e.g., data policies and dissemination approaches). Michener [1] also suggests ten points that can guide the process of creating

an effective data management plan for managing research data. After presenting this brief literature section, research procedures are outlined next.

3 Research Procedures

In order to carry out this study, articles in peer-reviewed literature (journals and selected conference papers) were considered in addition to non peer-reviewed material and examples being published by practitioners. At this stage, this collection was not comprehensive but enough for building a brief theoretical background mostly centered in data management as well as data management plan.

3.1 Peer-Reviewed Literature

A literature search was performed to identify relevant publications on data management subject, following recommended research procedures elsewhere [19]. Scopus and Web of Science were accessed to carry out the search, as they encompass a large number of publications from different areas. The key-words "Data management plan*" OR "research data management" were used searched in publication's title. No data filter was used. The results obtained in the databases were respectively 214 and 165 articles at Scopus and Web of Science data bases.

As this is an initial phase of an investigation, the focus was on the most cited articles as a criterion for relevance, using the databases' selection options. A retrospective procedure [19] was also employed to include relevant publications cited by the selected articles. Considering this 'fast-track' process, 24 documents were considered with the aim at constructing a brief literature background on data management and DMP, as mentioned earlier in this section and presented at previous section. This paper does not provide results from the literature analysis of those 24 documents in the results section (this is working in process). In addition, the literature search and analysis is going to be expanded in the near future.

3.2 Other Sources - Non Peer-Reviewed Material

This work also used secondary data from institutions, in the UK (Digital Curation Centre), in Portugal (University of Aveiro), and the European Commission. The Digital Curation Centre (DCC) has been widely cited in the literature, and they are very influential at the practice level as well. As many other universities in Europe and in the USA, University of Aveiro has provided information throughout various sources, seminars, reports, blogs, and webinars on data management and the development of data management plans in the context of the Open Research Data Pilot in Horizon 2020 from the European Commission [20].

3.3 Work Purpose

The objective of this work is to highlight some characteristics related to the life cycle of data management for research, in addition to some examples provided either from some

academic practices (e.g. internal documents associated with data management life cycle) or from the peer-reviewed literature (e.g. recommendation of points for constructing a DMP by ref. [1]). The authors of this paper also understand that the knowledge related to data management plan (DMP) might help beginners when starting to deal with this subject.

4 Results: Some Examples of Application

4.1 Developing a Data Management Plan

Digital Curation Centre [21] provides guidance and examples for building a Data Management Plan. There are contents that researchers typically expect to cover in a DMP, related to the following categories for data management [22]: (i) administrative data; (ii) data collection; (iii) documentation and metadata; (iv) ethical and legal compliance; (v) storage and backup; (vi) selection and preservation; (vii) data sharing; and (viii) responsibilities and resources. Table 1 provides a summary of those categories and summarises its contents.

Example of Documents of 'Administrative Data' in a University. Currently, the University of Aveiro participates in 433 national projects and 95 international projects [23]. As the university progress towards its goals, gradually it creates enormous amount of data that need to be managed. This instance considers research the data organization process used in an international project (Erasmus+Programme). One of the goals of this research project is to contribute to the Europe 2020 Strategy for growth, jobs, social equity, and inclusion, as well as the aims of the strategic framework for European cooperation in education and training - ET 2020 [24].

The identification data of the proposed ideas and participating institutions are depicted in Fig. 3, which shows two forms for data recording. This example illustrates the initial process of the program, in which several European organizations, mainly linked to education and research, come together to discuss ideas and define joint projects to be supported by the Erasmus+programme.

The forms in Fig. 3 provide basic data before research project initiation within the scope of 'Administrative Data' category (see Table 1). The contents are also part of the DMP presented by Digital Curation Centre, highlight in the next example.

After summarising the categories of a DMP, other examples are provided next.

Example of a DMP Checklist. DCC [25] synthesises through a checklist that presents the main questions or subjects that researchers may want to cover when writing a DMP (see Fig. 4).

4.2 Recommendations for Developing a Suitable Data Management Plan

Michener [1] recommends ten points for constructing an effective DMP, as summarised in Fig. 5.

Table 1. Categories and their contents for a DMP (based on ref. [22]).

Categories	Brief description
Administrative data	Document basic information in order to identify the plan (e.g. project title and summary), researcher details, applied policies, other procedures, etc.)
Data collection	Describe data collection and procedures to do so (e.g. existing data that can be reused, standards/methodologies to be applied, adopted quality assurance, etc.)
Documentation and metadata	Taken into account what information is needed for the data to be read and interpreted in the future (e.g. estimate how much time and effort are needed, establish documents and metadata that goes together with the data, metadata standards to be adopted, including reasons to do so, etc.)
Ethical and legal compliance	Consider any ethical, legal issues, or constraints that may be a concern for data sharing (e.g. data consent for sharing and preserving, protection for participants identification, data sharing postponement/restriction (e.g. related to patents, licensing data for reuse, etc.)
Storage and backup	Taken into account location of data storage and any implications this may have for backup, access, and security (e.g. sufficiency of storage, responsibility for backup/recovery, risk management, ensure secure access to people involved, etc.)
Selection and preservation	Determine which data are of long-term and should be preserved, including decision of best ways to preserve data (e.g. by depositing in repositories, data that must be retained/destroyed for contractual, legal, or regulatory purposes, expected research data uses, conservation and potential sharing, time and effort costing needed to prepare the data for preservation/sharing)
Data sharing	Consider which data that are to be shared and means to do so by taking into account that methods are dependent on various factors such as type, size, complexity, and sensitivity, etc. Also taken into account how people might acknowledge the reuse of data (e.g. citations) to gain impact (with whom to share the data and under what conditions, decision on making the data available, restrictions on data sharing, etc.)
Responsibilities and resources	Assign roles and responsibilities for every one involved in data management. Additionally, any resources needed to deliver the plan should be weighed up (e.g. DMP implementation responsibility, assure revision, split responsibilities among partners, needed resources to deliver the plan, additional specialist expertise/equipment, etc.)

PROJECT IDEA TEMPLATE

Title & acronym of the project	Include4DI – Inclusive Practices for Diversity and Integration
Programme	ERASMUS +
Key action	Key Action 2: Cooperation for innovation and the exchange of good practices
Action	Strategic Partnerships
Duration of the project	24 months
Deadline	26/02/2020
Budget	Maximum EU contribution awarded per 1 year of project implementation is 150 000 EUR 250.000
Developing organization	University of Aveiro
Contact person	Marlene Amorim
Erasmus+ priorities	Horizontal: Social inclusion Specific: Building inclusive higher education systems
Target group/s	Direct: Students, Educators Indirect:

SUMMARY/RATIONAL

The development of inclusive development is a foundational element the global agendas in contemporary societies. However, it requires continuous reflection and learning in order to improve our individual and organizational practices in what concerns the relationships and representation of human disabilities within work to achieve transformative, systemic change in work and life contexts.

Diversity and disability inclusion is part of a wider ambition for inclusive development that strives for the active participation and representation of all people regardless of age, gender, disability, ethnicity, race, class, religion, sexuality or any other characteristic.
The project Include4DI – Inclusive Practices for Diversity and Integration aims to contribute to the development and adoption of inclusive practices for in education, training and job integration contexts, notably trough the development of knowledge, tools and sharing practices that promote inclusive communication, anf foster the access and integration of individulas in a diverse and representative work and like context.
Estimating an accurate figure of the number of people with some form of disability is a challenging task to start with. Differences exist in the ways countries define disability; the quality and methods of data collection; reliability of sources; and disclosure rates.The Worls Report on Disability is a reference source in the topic and advances figure over a billion people, about 15% of the world's population, who have some form of disability. Disability can be defined as '... an evolving concept that results from the interaction between persons with impairments and attitudinal and environmental barriers that hinders their full and effective participation in society on an equal basis with others' - United Nations Convention on the Rights of Persons with Disabilities – or, in other words, disability can be addressed as the relationship between a person's impairment and their environment. As a human rights issue disability shares many common experiences with other groups that have been traditionally marginalised or excluded.

AIM AND OBJECTIVES

The project Include4DI – Inclusive Practices for Diversity and Integration aims to create and disseminate knowledge and tools that can support the development of more inclusive communication prectives in education, qualification and job integration contexts, in order to promote a wider access, integration and representation of diverse individuals in education, work and life contexts, facilitating the elimination of barriers to equal access to opportunities.
In order to achive its goals the project sets up to develop a toolkit and training tools to foster the inclisive communition and integration of individuals with diverse backgrounds and disability characteristics, including: i) develop a framework to identify and map diversity and disability

context and profiles, and build an awareness pack consisting in content and materials, in the form of cases and examples of diversity and disabilty inclusion challenges associated with communication in education and work contexts, building on the collection of evidence from accross the partner countries [O1]; ii) develop methods and tools to assist educators and recruiters in the development of inclusive communcation and content, including guidelines and examples of inclusive communcation, practical checklists to assess the inclusiveness of content of communication materials, to meet a set of selected/relevant profiles and contexts of diversity and disability [O2]; develop an online tool to support and make available the elements resulting from O1 and O2, and to integrate a tool to support the online and interactive assessment of the quality of communication materials and content prduced by educators and recruiters [O3]; create learning/training materials for educators, trainers and recruiters to deploy the use of O1, O2 and O3, pilot these materials and make them available to wider audiences [O4]; conduct a short training event/pilot involving participants from partner countries, and engaging representativs from the target audiences, including educators, trainiers and recruiters.

PROJECT OUTPUTS/ INTELLECTUAL OUTPUTS

Please list the outputs to be developed along with a brief description for each one.

IO1: Diversity and disability profiles and context tipology and characterization method

IO2: Methodology and guide to identify diversity and disability gaps in communcation and content materials

IO3: Online tool to disseminate diversity and disability integration tools and materials and incorporating online interactive function to assess the quality of communication materials

IO4: Tool kit for training educators, trainers and recruiters.

PROPOSED PARTNERSHIP

List here any organisation that has been already included in the partnership

A/A	ORGANIZATION	COUNTRY	ROLE	MAIN RESPONSIBILITIES
1	Uni Aveiro	Portugal	APPLICANT	IO1
2	EUROSUCCESS	Cyprus	PARTNER	IO3
3	DomSpain	Spain	PARTNER	IO2
4			PARTNER	
5			PARTNER	
6			PARTNER	

PARTNERS NEEDED

Describe a profile/s of the partner/s you are looking for...

The project is looking for partners from countries/contexts where cultural diversity is prevalent, where education and work contexts are addressing challenges in the integration and communication with diversified backgrounds and individual conditions (e.g. migrants).

Fim do documento

Fig. 3. Project idea template example.

Earlier points on DMP raised in Fig. 5 are similar than other sources. However, the author adds more specific details on procedures, tools, etc. as a useful guidance to the development of a DMP. It is worth noting that previous description is an extraction. Further contents can be found in ref. [1].

DCC Checklist	DCC Guidance and questions to consider
Administrative Data	
ID	A pertinent ID as determined by the funder and/or institution.
Funder	State research funder if relevant
Grant Reference Number	Enter grant reference number if applicable [POST-AWARD DMPs ONLY]
Project Name	If applying for funding, state the name exactly as in the grant proposal.
Project Description	**Questions to consider:** - What is the nature of your research project? - What research questions are you addressing? - For what purpose are the data being collected or created? **Guidance:** Briefly summarise the type of study (or studies) to help others understand the purposes for which the data are being collected or created.
PI / Researcher	Name of Principal Investigator(s) or main researcher(s) on the project.
PI / Researcher ID	E.g ORCID http://orcid.org/
Project Data Contact	Name (if different to above), telephone and email contact details
Date of First Version	Date the first version of the DMP was completed
Date of Last Update	Date the DMP was last changed
Related Policies	**Questions to consider:** - Are there any existing procedures that you will base your approach on? - Does your department/group have data management guidelines? - Does your institution have a data protection or security policy that you will follow? - Does your institution have a Research Data Management (RDM) policy? - Does your funder have a Research Data Management policy? - Are there any formal standards that you will adopt? **Guidance:** List any other relevant funder, institutional, departmental or group policies on data management, data sharing and data security. Some of the information you give in the remainder of the DMP will be determined by the content of other policies. If so, point/link to them here.
Data Collection	
What data will you collect or create?	**Questions to consider:** - What type, format and volume of data? - Do your chosen formats and software enable sharing and long-term access to the data? - Are there any existing data that you can reuse? **Guidance:** Give a brief description of the data, including any existing data or third-party sources that will be used, in each case noting its content, type and coverage. Outline and justify your choice of format and consider the implications of data format and data volumes in terms of storage, backup and access.
How will the data be collected or created?	**Questions to Consider:** - What standards or methodologies will you use? - How will you structure and name your folders and files? - How will you handle versioning? - What quality assurance processes will you adopt? **Guidance:** Outline how the data will be collected/created and which community data standards (if any) will be used. Consider how the data will be organised during the project, mentioning

Fig. 4. Example of part of a checklist for a DMP (v.4.0, 2014) [25].

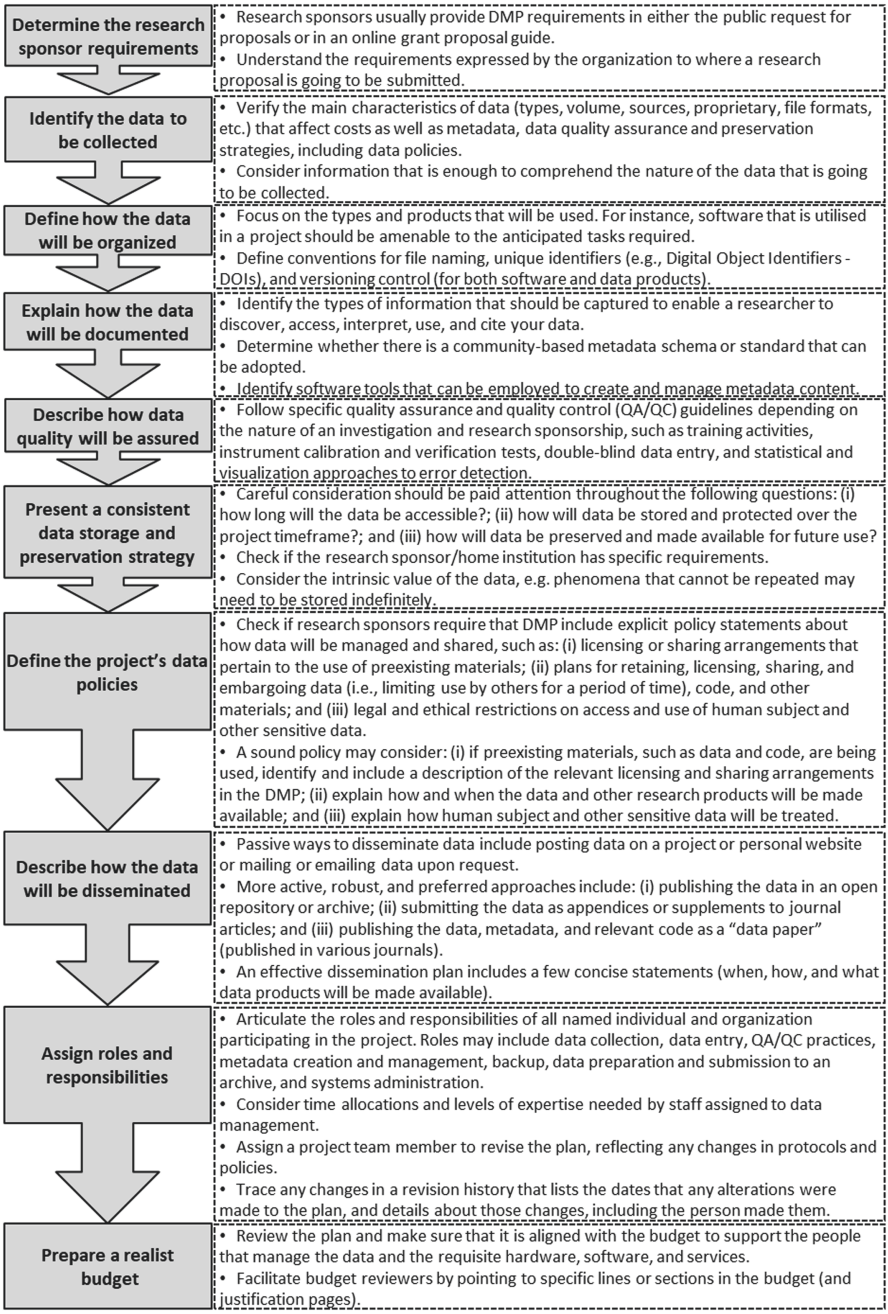

Fig. 5. Guide for creating an effective DMP (constructed based on ref. [1]).

5 Concluding Remarks

Currently, it is undeniable the sharp exponential growth in the amount of data. Thus, it is of paramount importance to ensure that researchers possess the knowledge and to employ best practices with regard to their data during their research as well as after completion. Concerning on all stages of data life cycle is crucial in research, chiefly taking into account the demands from funders.

This work concisely explores the characteristics of the life cycle of data management for research. At this point of this work, the authors expect to start (and expand) this discussion to the research practices in the field of industrial engineering because this is usually omitted, methodologically speaking. As illustrated in the present study, a data management plan is one of the important instruments and should be considered with care when designing and applying it. In this context, it is also relevant to provide a comprehensive support for managing research data generation, preservation, and sharing for reproducibility as well as for further applications. This may include instructions on best practices in data management to graduate students, which is relatively rare in developing countries like Brazil, for instance. Future work may consider providing a structure and guidance for research students in the field of industrial engineering as a valuable avenue to explore.

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