

# RESEARCH DATA MANAGEMENT: A PRACTICE TO OPEN THE BLACK-BOX OF SCIENTIFIC RESEARCH

GESTÃO DE DADOS DE PESQUISA: UMA PRÁTICA PARA ABRIR A CAIXA PRETA DA  
PESQUISA CIENTÍFICA

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**JITA:** I. Information treatment for information services

**e-Location:** 019031

**ABSTRACT**

This paper discusses how the Open Science has constituted a new approach to the scientific knowledge generation process, based on the collaborative form that scientific production is being created and outreach. Traditional research outcomes such as papers, dissertations and theses, although available in open access, can be compared to a black box, under the Actor-Network Theory (ANT) perspective, since they are considered the final and closed result of a determined researcher's or a research group's analysis. This paper, mainly bibliographic, uses bibliographical and bibliometric research as methods of data treatment, followed by a systematic review of the literature. The aim is to highlight how the research data availability has agency within the science process and the scholarly communication. To this end, some of ANT's concepts are used to identify the role of research data within the network, built of human and nonhuman elements together. As results, this paper evidence how the research data availability provides new information resources, allowed mainly by the scientific activity feedback.

**KEYWORDS**

Scientific data. Scientific information. Data - Life cycle. Actor-Network Theory.

**RESUMO**

A Ciência Aberta tem constituído uma nova abordagem para o processo de geração de conhecimento científico, com base na forma colaborativa que a produção científica tem sido criada e comunicada. Os tradicionais resultados de pesquisa como artigos, dissertações e teses, ainda que disponíveis em acesso aberto podem ser comparados à uma caixa-preta, de acordo com a perspectiva da Teoria Ator-Rede (TAR), constituindo o resultado acabado da análise de um determinado pesquisador ou grupo de pesquisadores. Este artigo, eminentemente bibliográfico a partir de descritores, utiliza a pesquisa bibliográfica e bibliométrica como métodos de tratamento dos dados, seguido de revisão sistemática da literatura. O objetivo busca evidenciar como a disponibilidade dos dados de pesquisa interfere no processo de geração e de comunicação científica. Para tal utiliza-se das concepções da TAR na identificação do papel dos dados de pesquisa dentro de uma rede, composta por elementos humanos e não humanos. Como resultados, demonstra-se a partir do ciclo de vida dos dados de pesquisa, de que forma a disponibilidade destes produz novos recursos de informação, viabilizada pela retroalimentação da atividade científica.

**PALAVRAS-CHAVE:**

Dados Científicos. Comunicação Científica. Dados - curadoria digital. Teoria Ator-Rede.

## 1 Introduction: research data as an element of open science

Several agencies recognize the importance of research data and require proper management of this data, highlighting the need to ensure the means and mechanisms for preserving and reusing it through policies that regulate the opening of publicly-funded research data instituted more than a decade ago in several countries, such as:

- (i) United States: National Library of Medicine (2018a; 2018b); National Institutes of Health, (2003; 2010); National Science Board (2005); National Science Foundation (2007; 2010); Office of Science and Technology Policy (2013);
- (ii) Canada: Social Sciences and Humanities Research Council of Canada (1990); Industry Canada (2014); Tri-Agency (2014); Research Data Canada (2016);
- (iii) Countries of Europe: Organization for Economic Cooperation and Development (2007; 2015); European Commission (2016); The Engineering and Physical Sciences Research Council (2018); The Wellcome Trust (2017).

The United States National Institute of Health (NIH) requires that articles from all Institute-funded research be deposited in the PubMed Central institutional repository (GRIGG, 2015). Currently, it also requires research data to be available in open access (NATIONAL LIBRARY OF MEDICINE, 2018). The National Science Foundation (NSF) requires a data management plan and the availability of this data in open access (GRIGG, 2015). The European Horizon 2020 program (H2020), the largest scientific research program ever created in the European bloc (EUROPEAN COMMISSION, 2014) has open access publication as a requirement for participation and scholarships (EUROPEAN COMMISSION, 2016a, pp. 2016-2019; 2016b). Such accessibility, therefore, represents a new approach to the scientific process based on cooperative work and new forms of knowledge diffusion through digital technologies and new collaborative tools (EUROPEAN COMMISSION, 2016c, p. 33). Facilitated access and open data are practices included in a broader concept, strengthening the Open Science proposal (PONTIKA *et al.*, 2015).

The Organization for Economic Co-operation and Development (OECD) (2015) conceptualizes Open Science as a way of "allowing access to publicly funded primary research results - publications and research data - available to the public in digital format without or with minimum restriction" (ORGANIZATION FOR COOPERATION AND ECONOMIC DEVELOPMENT, 2015, p. 7). Open Science therefore involves a number of movements that tend to suppress barriers to sharing any kind of research findings, resources or data, methods or tools, at any stage of the scientific research process (ORGANIZATION FOR COOPERATION AND ECONOMIC DEVELOPMENT, 2015).

Research data has been not only an object of study, but also elevated to the status of Information Science research subarea, along with open access to scientific information and

open science (PINHEIRO, 2018). Although there is no consensus, and vary across disciplines, research data refer to “actually recorded material commonly accepted in the scientific community as necessary to validate research results” (THE ENGINEERING AND PHYSICAL SCIENCES RESEARCH COUNCIL, 2018, online - our translation). Therefore, it is inferred that research data are not only the finalized scientific papers, such as theses, dissertations and articles, these are the most common results in research processes (SAYÃO; SALES, 2015). These data are research products that cover a wide range of record types and can be structured and stored in various file formats. While most of this data is digitally sourced, all search data is included in the concept, regardless of the format in which it is created.

In research data management are examples of heterogeneous elements, which also attribute complexity to the management and sharing of research data, aspects such as: digital preservation, data curation processes and data quality (SAYÃO; SALES, 2012b). ; protocols, system interoperability and institutional governance (SAYÃO; SALES, 2015), behavioral and cultural barriers to data sharing (CURTY, 2016) copyright and intellectual property (MEDEIROS, 2016), data management support services (CARLSON, 2014).

Given the complexity of implications for sharing open data and establishing an Open Science culture, the purpose of this paper is to highlight whether the availability of open access research data can interfere with research and scientific communication activities, in particular. virtual environments. To this end, we sought to identify the actors involved in scientific production according to the main concepts of the Actor-Network Theory (ANT) *corpus*, favoring the description of those who reveal the network and its dynamics, based on the methodological approach of the life cycle. of data and scientific research. From the perspective that research data are the object of study of Information Science (PINHEIRO, 2018), having complexity as an inherent development of its interdisciplinarity, the use of ART is justified as an appropriate form of network analysis. "narrowing the dialogue between Information Science and Sociology" (FRANÇA; PINHO NETO; DIAS, 2015, p. 137).

In analyzing research data as a part of the scientific communication infrastructure, Medeiros (2016) uses the Actor-Network Theory (ANT) approach, describing the interdependencies that constitute a network sustained by connected variables that only persist from the agency of human and non-human actors. For this author, the network reveals the explicit and implicit structures that emerge from data qualified as social and collective constructs, which reorganize scientific communication based on data availability (MEDEIROS, 2016, p. 300).

In this sense, the choice of the Actor-Network Theory (ANT) as an epistemological approach will allow to follow the actors, among them those who, for Freitas and Leite (2019), are considered the main involved in scientific communication as researchers, publishers. libraries, funding agencies and universities. This analysis, added to the other methodological procedures that outline this research, are described sequentially. The paper is organized into sections (1) Introduction; (2) Methodology, in which methodological descriptions are

presented and detailed; section (3) discusses the research data from the perspective of Actor-Network Theory; section (4) gives an overview of the main elements of ART adopted in this study; Section (5) presents the actors' descriptions, the dynamics of the network and its effects, and Section (6) concludes with the final considerations.

## 2 METHODOLOGY

The methodological procedures used for the development of this research followed the following sequence of activities: a) basic literature review of the Actor-Network Theory; b) bibliometric survey and selection of articles related to Research Data Management; c) selection of articles dealing with Data Management life cycles; d) description of the role of data in the dynamics of the scientific research cycle, considered an element of the scientific production and communication network. The basic theory is based on the Actor-Network Theory from Callon (1986a; 1986b; 1993); Callon, Law and Rip (1986); de Latour (1983, 1992; 1993; 1995; 1998; 2000; 2001; 2006); de Latour and Callon (1981); Law (1993) and Sismondo (2010).

From the bibliographical review of the basic theory, descriptors were identified as search terms in the bibliographic survey in the databases covering the area of Information Science, available on the EbscoHost Portal, in addition to Google Scholar. The method of setting the descriptors "is an intellectual technique for specifying the subject of information and retrieval" (MOOERS, 1972, p. 31). The terms used for searching in the data management research, were Research Data Management and Research Data Lifecycle. The research was delimited in the scope of Social Sciences and in articles published in the last five years (2014 to 2019). At Google Scholar, the research was conducted over the past two years (2018-2019).

Search results were selected according to the number of articles retrieved from the following information sources: Academic Search Ultimate (23 results), Information Science & Technology Abstracts with Full Text (ISTA - 21 results), Computers & Applied Sciences Complete (3 results) Library and Information Science & Technology Abstracts (LISTA - 1 result), in addition to the open access publications listed in Google Scholar (115 results).

The result of the bibliometric survey was used for the Systematic Literature Review (GUERTIN; BERNHARD, 2005; CANADA, 2004), in order to base the selection of articles related to the Research Data Management together with the selection of articles dealing with Data Management cycles. The result of the systematic analysis was produced after the execution of the macro steps of the bibliographic survey and the systematic analysis itself, which comprised the following sub steps: (i) Subject specification; (ii) Definition of information localization strategies; (iii) Selection of documents; (iv) extraction of

information; (v) Processing of information and (vi) Text production (GUERTIN; BERNHARD, 2005; CANADA, 2004). The result pointed to data management cycle models proposed by prominent institutions that advocate for access to data within the scientific community itself, becoming a reference for researchers and data managers (BALL, 2012).

Among the models analyzed in this paper, we highlight the Data and Scientific Research Life Cycles described in Table 1. For this study we selected the Social Sciences Data Life Cycle Model, the Inter Data Life Cycle. University Consortium for Political and Social Research (ICPSR, 2012), as a model of the Social Sciences and which emphasizes best practices in data management through the data lifecycle, working closely with researchers who submit their sets of data for the use of the research community (INTER-UNIVERSITY CONSORTIUM FOR POLITICAL AND SOCIAL RESEARCH, 2012, p.5).

**Table 1.** Life cycle models of data and scientific research analyzed - 2019

LIFE CYCLE	INSTITUTION / AUTHOR	DATA LIFE CYCLE	DESCRIPTION / STEPS
Research Data Lifecycle	DataONE Federation	DataONE Data Lifecycle. (MICHENER; JONES, 2012)	Plan, collect, secure, describe, preserve, discover, integrate, analyze.
Research Data Lifecycle	Digital Curation Centre – DCC	DCC Curation Lifecycle Model. (HIGGINS, 2008)	Creation, collection, preservation and maintenance of metadata sufficient to enable the data to be used and reused for as long as it is valid and warrant curation. Preservation planning, strategies, policies and procedures for all curation actions.
Research Data Lifecycle	Inter-university Consortium for Political and Social Research – ICPSR	Data Life Cycle ICPSR. (ICPSR, 2012)	Project Research and Data Management Plan, project start, data collection and file creation, data analysis, data preparation for sharing, data warehousing.
Research Data Lifecycle	Rüegg <i>et al.</i> , 2014	Data life cycle, including data reuse. (RÜEGG <i>et al.</i> 2014)	The data life cycle includes the description and preservation of data. A traditional project includes planning, data collection, data quality, control and analysis. Proposes projects that reuse existing data for all or part of their analysis, including planning, collection, quality assurance and quality control (QA / QC), additional data discovery, data integration, and finally analysis steps. To complete the data lifecycle, you need to add data documentation (metadata) and data archiving steps to a publicly accessible repository.
Research Data Lifecycle	The Data Documentation Initiative - DDI	DDI Combined Life Cycle Model. (STRUCTURAL REFORM GROUP, 2014)	A lifecycle model for research data, particularly in the social sciences, which provides for the concept of research, data collection, data processing and archiving, distribution, discovery and analysis of data,

LIFE CYCLE	INSTITUTION / AUTHOR	DATA LIFE CYCLE	DESCRIPTION / STEPS
			and reuse of data. .
Research Data Lifecycle	UK Data Archive	UK Data Archive Data Lifecycle. (CORTI <i>et al</i> , 2014)	Data Collection, Data Processing and Analysis, Publishing and Sharing, Long Term Management, Data Reuse.
Research Cycle	I2S2 Partners	I2S2 Idealized Scientific Research Activity Lifecycle Model. (I2S2 PROJECT, 2011)	Focuses on researcher research activities: publishing activity, administrative activity, and archiving activity.
Research Cycle	Green e Gutmann (2007).	The social science research life cycle (GREEN; GUTMANN, 2007).	Discovery and planning, initial data collection, Final data preparation and analysis, Publishing and sharing, Long term management. Includes institutional digital repositories with no subject-specific focus and subject or domain-specific data files. It foresees the repositories of institutions and the roles and activities of the partnership during the research life cycle.
Research Cycle	UCF Libraries RLC Committee	Research Lifecycle at University of Central Florida (UCF LIBRARIES RLC COMMITTEE, 2012).	Planning, Project Management, Publishing and Presentation, Preservation and Dissemination, Prestige, Impact and Discovery.
Research Cycle	Lyon (2003)	The Scholarly Knowledge Cycle (LYON, 2003).	Features information workflows typical of the search cycle, based on a project in which large amounts of varying data are generated. Search results are peer-reviewed journal articles.

Source: Result of Systematic Literature Review (RSL)

We sought to identify which interferences research data, when available, can promote in the contemporary scientific research cycle in data-driven virtual environments (SAYÃO; SALES, 2016). In this perspective, to verify if the availability of data itself acts and influences the network dynamics, the Actor-Network Theory was followed. For this work, the identification of the scientific knowledge production network will be based on the description of the actors involved in the research and scientific communication process, using for this purpose the life cycle of the scientific research activities themselves, seeking to highlight the juxtaposition. between human and nonhuman elements. For the contribution of the description, it is necessary to extract knowledge from the Actor-Network Theory, the basis of this work and used as a social analysis tool (CALLON, 1993). How some Theory constructs relate to research data are described in the next section.

### 3 Research Data Under the Actor-Network Theory Perspective

Both science and technology (S&T) are powerful forces in modern industrialized society, however, the way their force is created and developed is obscure (CALLON; LAW; RIP, 1986, p.3). For these authors, “the idea that there is a special scientific method, a domain where truth thrives at the expense of power, is a myth” (CALLON; LAW; RIP, 1986, p.4). In seeking a contribution to the study of the dynamics of science, Callon, Law, and Rip (1986, p. 3) argue that “an understanding of the dynamics of science is possible only when the strength of science in everyday society is considered”.

For Feenberg (2010, p. 69), S&T has a great influence on people's daily lives, but its development is still under the control of the masters of technical systems, obscuring political democracy itself. Feenberg (2010) also argues that modern technology, if administered in another social context, could be an instrument of democratization. This understanding of social and scientific change requires abandoning the dichotomy between science and politics, and understanding these transformations presupposes that actors are followed, "not only in palaces (when they do politics), but also in laboratories (when they do science). "(CALLON; LAW; RIP, 1986, p. 4).

According to Grigg (2015), some principles that are linked to the opening of research data and corroborate these perspectives of democratization of science are: advertising, giving researchers greater visibility; the possibility of data reuse in new connections; the induction of network collaboration and the transparency of the data used for results; the acceleration of the production of new research; compliance with research funding rules; improving research investments and reducing their duplication; the promotion of reproducibility, verifiability to ensure good scientific practice; access to research of social importance and a greater awareness of the challenges of society.

Two changes contributed to the democratization of access to texts produced in research (SETENARESКИ, 2013): the first was the movement for open source software, which provided the technological infrastructure necessary for free access. Begun in the 1970s, after several developments in the free software movement, it favored the development of tools for publishing and making scientific production open and free (EUROPEAN COMMISSION, 2006). The second concerns the policy changes of funding agencies that have fostered a social environment conducive to the democratization of science, which, according to the Open Science and Research Initiative, is the main premise of open research (OPEN SCIENCE AND RESEARCH INITIATIVE). 2014, p. 2).

On the other hand, Latour (2000), when addressing the process of scientific construction, denounces the vulgarization of science to the majority of lay people in society, keeping scientific activity in a black box, which only the social studies of Science,

Technology and Society (CTS), have been trying to open (LATOUR, 2000, p. 33-34). “The black box contains what no longer needs to be rethought, things whose content has become a matter of indifference” (LATOR; CALLON, 1981, p. 284). Latour's methodological proposal for the study of the construction of facts occurs simply, as he calls it, from the best of all guides: following the scientists themselves. Rather than analyzing a closed black box, or the end result, such as scientific facts or technical artifacts, he prefers to follow in the footsteps of scientists at a time and place where their constituent elements are still unstable, being constructed.

From this approach, the research process that generates the data is much more difficult to replicate, as it involves several resources (LATOUR, 2000, p. 115). Latour (2000) describes the implications and circumstances of the construction of scientific facts and artifacts to the point of becoming black boxes, that is, the moment and that these scientific resources are finished, in which all their complexity is encapsulated in a concept. or in an artifact in a way that becomes unquestionably accepted. Black boxes are the last stage of scientific construction. Any questioning of the stabilized object costs a lot; To disagree and argue, opening the black box is, for Latour, an expensive, perhaps unworkable task (LATOUR, 2000, p. 116). These questions demand to go all the way, from the access to the texts, the researchers, the research institutes that represent the governments and the public policies by which these institutes are regulated, also to the laboratories, the raw materials, the field research, the surveyed data, to the natural or social environments for collecting this data, the scientists' skills in conducting their experiments.

Roughly speaking, the research results, published in the form of scientific articles, theses and dissertations, can be compared to a black box. They are consolidated from theories, data and methods. One way to open these black boxes would be from the available research data generated by the scientists' work before it becomes only the published results of their analysis. Given availability, re-analyzing data from other approaches can maximize the resources employed in collecting this data, either by re-analyzing the data or by ratifying studies already prepared. Black box verification can be done at an acceptable cost.

The importance of the availability of research data is mainly due to the possibility of understanding the process of generation of that knowledge, without obscurity. From this perspective, the availability of research data would increase their reuse not only for validations, but for new inferences from different approaches, making the process of scientific construction transparent, open and democratic.

It is not intended here to reduce scientific and technological activities to the transmission of literary inscriptions, however, it is considered that these records are a central feature of Science and Technology (S&T), as the text reveals the authors' world-building strategy. (CALLON; LAW; RIP, 1986, p. 10), and the communication of scientific

production is centered on the dissemination of research results, making non-human elements protagonists. ART's proposal to society is that non-human elements add to humans to form the 'collective', an idea that transcends the very notion of 'society'. The idea of collective rather than society is one of the main concepts of ART and among other elements described in the next section.

#### 4 Verview of the Main Elements of the actor-network theory (ANT)

For Latour (1998) knowledge is built with the involvement of a heterogeneous network of materials, representations, financing, economic pressures, political disputes, in an endless chain of elements. The Network refers to flows, circulations, alliances, movements, not referring to a fixed entity, but to the connections or interactions that transform dispersed resources into a network (CALLON, 1986b). It is the interactions of the actors that form a relatively stable set of associated entities that achieve some durability.

**Actors** are entities that make up networks and have action, interference, or in Latour's terminology, they have “agency”. This makes them “acting”, that is, can only be considered an actor who (or what) acts in relations with other elements of the network. The actor is the one who promotes the alliance, that is, who or what entices the enticement of other entities towards a goal (SISMONDO, 2010). The concept of actor is central to ART, because it is through its strength to mobilize others that the network works. The Agency, non-human acting, is central to ART. In several examples of the agency attributed to non-human elements, it is demonstrated how these elements played a “role” in the process and the final results of each project's objectives (CALLON, 1993; CALLON, 1986a; LATOR, 1995; LAW, 1993). The theory implies the enticement of allies for the establishment of a stable network in which the results depend on the management of all entities that support the same objective.

**Laboratories** support the ART assumption that Science and Technology - S&T - translate matter and action into one another, in which nature is transformed by its tools. Tools in laboratories give scientists the power to act on nature for the manipulative features they provide. The power of S&T lies in the arrangement of actors and the power of laboratories and their functionalities, which are tied to observations, formulations and manipulations. However, for the Social Sciences, the scientific text is the functional equivalent of the laboratory: “[...] (the text) is the site of tests, experiments and simulations. And it depends entirely on the precise way it is written - and each new topic requires a new way of dealing with a text” (LATOR, 2006, p.347).

**Translation** comprises translating the interests of various actors so that everyone works together and in agreement (SISMONDO, 2010, p.90), symmetrically, in a process

called sociology of translation (CALLON, 1986a). The notion of translation comprises the process of continually changing goals and interests that occur in the various stages of the relationship between nature and society (CALLON, 1986a).

**Generalized symmetry** is the idea of a general theory of relations between heterogeneous elements. Law (1993) highlights the generalized symmetry, attributing to human elements or not the same type of analysis, and the reciprocal definition in which actors are the entities that influence other elements (LAW, 1993, p. 132). The generalized symmetry consists in not categorizing the heterogeneous elements that make up the network, whether processes, entities, objects, people, institutions or rules or machines, natural forces or social groups. It is necessary to deal with heterogeneity in all its complexity (LAW, 1993, p. 117).

Thus, from the perspective of ART (LATOUR, 2001), in which human and non-human elements weave a certain network, it can be inferred that researchers, funding agencies, educational institutions, laboratories, bits, electronic archives in any format, academic production storage systems, academic libraries, online search engines for retrieving information and research, as well as the research data itself, constitute, among other elements, the process of research and generation of scientific knowledge.

## 5 Results: actor descriptions, network dynamics and its effects

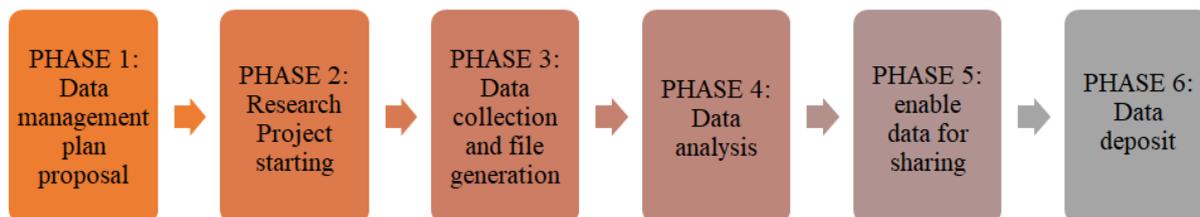
The research data constitute the central element that subsidizes the research results, since it is the data collected and used for analysis that will be later treated and condensed in the form of results published in the scientific texts, as inferred from Sayão and Sales (2012a, 2012b, 2016). If the inscriptions are the foundation of scientific texts, as stated by Latour (2000), then the research data are part of the support of the results of the research itself. The following sections discuss in section 5.1 what are the data management steps adopted for this study and section 5.2 demonstrate how the scientific communication network can be deployed based on the availability of research data.

### 5.1 Data Management Steps

Data produced as part of research has a wide variety of formats, from statistics and experimental results to interview records and transcripts (BORGMAN, 2012). In order to manage this data, several data lifecycle models have been proposed (BALL, 2012; GREEN; GUTMANN, 2007; I2S2 PROJECT, 2011; LYON, 2003; UCF LIBRARIES RLC COMMITTEE, 2012).

The sequential data management steps in Figure 1 represent the activities the researcher will need to perform in order for his research data to be made available and should be incorporated into the research methodology itself (INTER-UNIVERSITY CONSORTIUM FOR POLITICAL AND SOCIAL RESEARCH, 2012, p.8). Figure 1 shows the life cycle stages proposed by the ICPSR and accepted in this study as a conducive bias.

**Figure 1.** Data management steps proposed by the Inter-university Consortium for Political and Social Research (ICPSR)



Source: Adapted from ICPSR (2012, p. 9).

Each of these steps carries numerous developments such as compliance rules, management practices, protocols, formats and legal requirements so that data is available not only openly but also securely, with attested quality and preserved against technological obsolescence. Thus, research data no longer appear as by-products of research activities and become a focus of great interest to the entire scientific world (SAYÃO; SALES, 2016). *Anjos e Dias* (2019) reinforce the role of the data lifecycle as a supporting instrument at various stages of the scientific research process. Therefore, the data constitute part of the non-human elements acting in the research and scientific communication network.

### 5.2 The scientific communication network from the availability of research data

Traditional models of scientific communication covered the availability of finished research results, after the researcher went through all the processes involved from the initial research to the assimilation and the use of the results to create new research and, consequently, new documents, as Sayão and Sales describe (2012a, p.128).

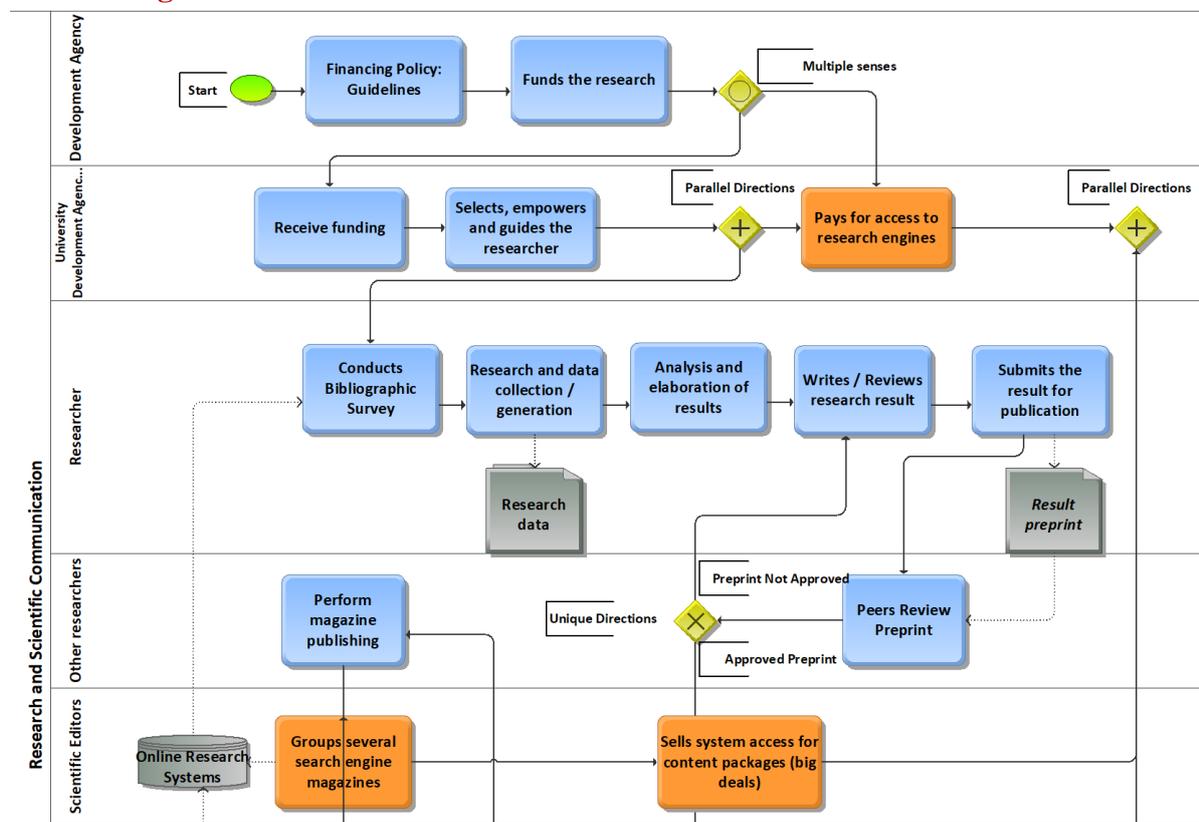
By following the actors of traditional models of research and scientific communication, researchers, peers from the scientific community, universities, libraries, funding agencies, publishers, and journals, with their online search systems and their own society, it is possible to see how agency exerts in the dynamics of the scientific communication network, as it interferes and modifies the research activities. Figure 2 presents the traditional model of scientific research activities based on the life cycle models of scientific research activities (GREEN; GUTMANN, 2007; I2S2 PROJECT, 2011; LYON, 2003; SAYÃO; SALES, 2012a; UCF LIBRARIES RLC COMMITTEE, 2012).

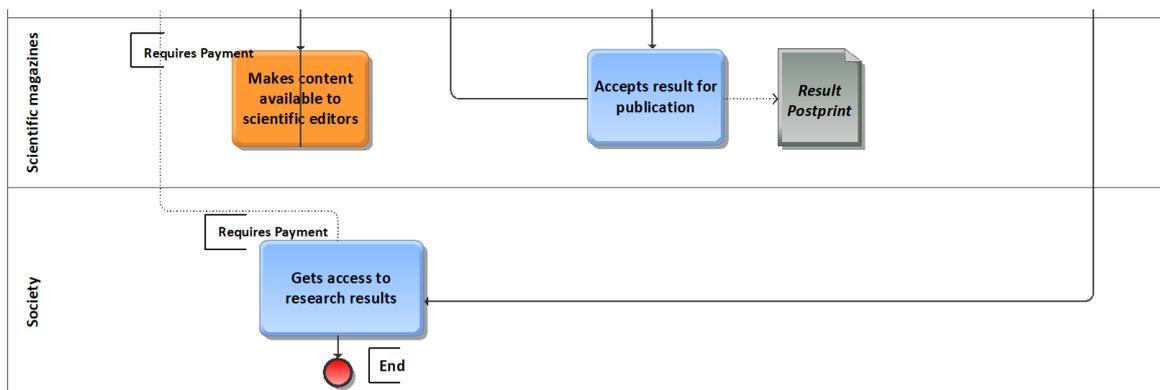
The proposed model represents the parties involved and their activities performed. Each of the parts is identified in blocks that are called lanes, the activities being described in the sequence in which they occur, within the domain of the respective area of each involved part. The lanes identified in figure 2 are the actors of the traditional models of research and scientific communication. The graphic representation of the activities was highlighted by colors to demonstrate the actors' inferences. Orange activities are linked to restricted (paid) access to search results. All other rectangular representations, in blue color, refer to the sequential activities of research and scientific communication.

From the movement for open access to access policies, institutional repositories have changed the form and especially the cost with which search results are made available (RODRIGUES, 2008 apud SAYÃO; SALES, 2012a, p.128-129). For Pavão, Rocha, and Gabriel Junior (2018), repositories play a vital role in disseminating research data. In Brazil there is a relevant role in the development of institutional repositories for dissemination of completed academic research, but the country still has no support for the creation of data repositories (PAVÃO; ROCHA; GABRIEL JUNIOR, 2018).

Figure 2 presents the scientific research activities and the possible changes by the arrangement of new elements in the network, such as open access to search results and the availability of data in specific repositories.

**Figure 2.** Traditional model of scientific communication research activities





Source: Adapted from the literature (SAYÃO; SALES, 2012, p. 129-131; GREEN; GUTMANN, 2007; I2S2 PROJECT, 2011; LYON, 2003; UCF LIBRARIES RLC COMMITTEE, 2012). Use of BPMN 2.0 notation (OBJECT MANAGEMENT GROUP, 2011).

**Subtitle:** Research and Scientific Communication Activities Restricted Access

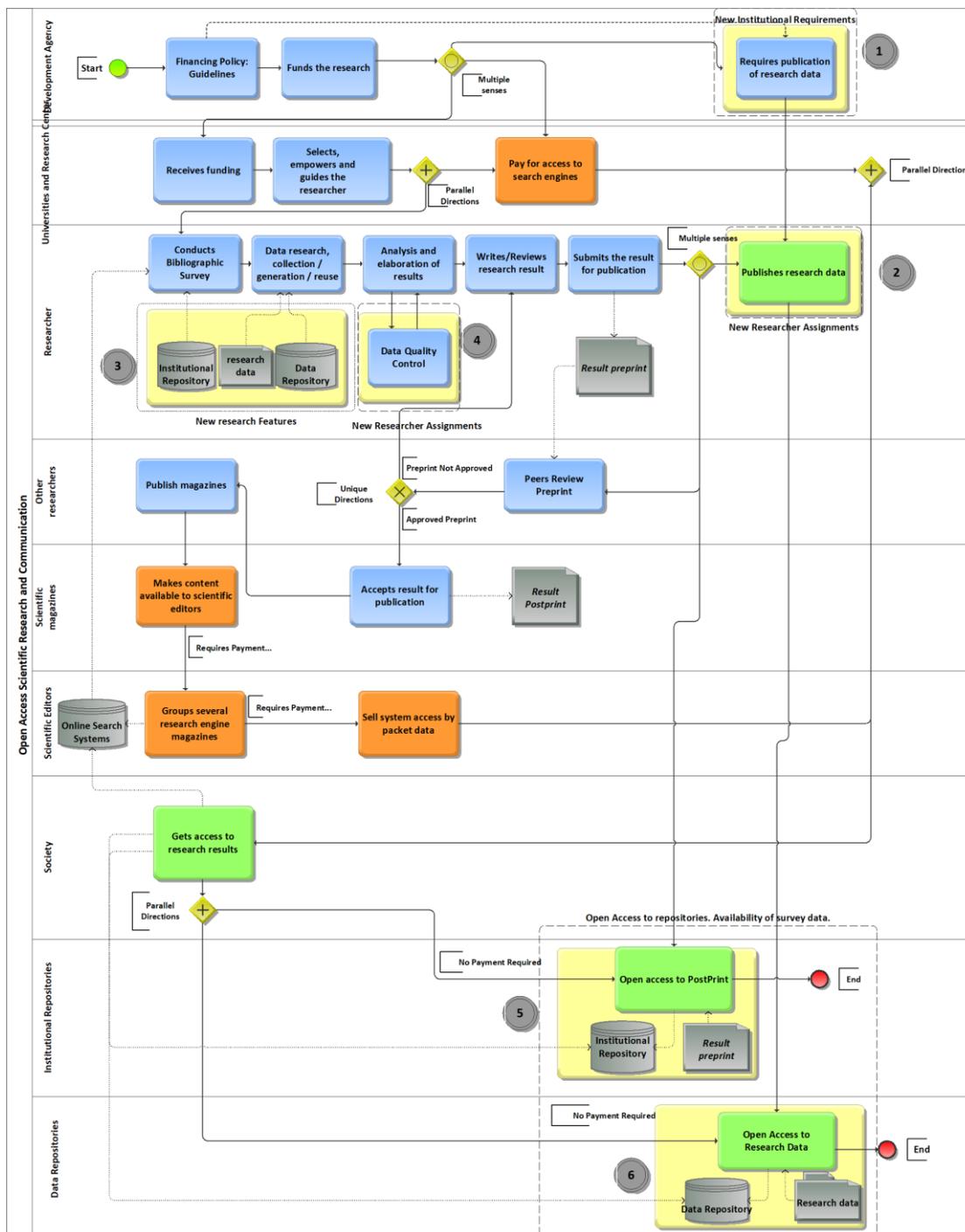
Orange activities are tied to restricted (paid) access to search results, where scientific publishers bundle content and provide access to institutions through high-cost (Big Deals), which form the oligopoly of scientific publications. (ASSOCIATION OF RESEARCH LIBRARIES, 2012; BOSCH; HENDERSON, 2012).

Activities were added in green, representing the influences attributed to the process from the advent of open access, which brings as its central prerogative "to make knowledge available to anyone free" (FECHER; FRIESIKE, 2014, p. 20). Activities highlighted in yellow represent developments and activities based on the availability of open research data.

Deeply, in the area of funding agencies, there is a requirement to publish research data in the face of institutional policies that provide for this attribution to the researcher. In the researcher's streak then emerges another activity, that is, the publication of these files that were formerly by-products in the traditional model, since they were not published in the activities of scientific communication (SAYÃO; SALES, 2016) and now, when they are managed starting from the data lifecycle (figure 1), the search cycle is incorporated as a researcher assignment to make it available in open access. However, even if there is a new activity for the researcher, the implications of this change are directly beneficial to the research activity itself, as it allows feedback from the search process and data location.

Available data are possible to be located and reused in other investigations, according to the numerical indication 3 - figure 3. In addition to the traditional search systems that require payment for access, open resources, made possible by the feedback of scientific activity, are available to the researcher. as other scientific information resources, broadening the scope of information sources for free. Access to the institutional repositories that bring the results of other research (numerical indication 5), and to the data repositories of other researchers (numerical indication 6), allows the democratization of scientific production and ultimately benefits society as a whole. However, the availability of data implies a quality control of the researcher to ensure adequate reuse, which is the methodological option of the available data, as indicated numerically 4.

**Figure 3.** Open access and data availability in Search activities



Source: Adapted from the literature (SAYÃO; SALES, 2012, p. 129-131; GREEN; GUTMANN, 2007; I2S2 PROJECT, 2011; LYON, 2003; UCF LIBRARIES RLC COMMITTEE, 2012). Use of BPMN 2.0 notation (OBJECT MANAGEMENT GROUP, 2011).

**Subtitle:** Research and Scientific Communication Activities Restricted access Open Access Availability of data

Figure 3 shows the numerical indications 5 and 6, which refer to the availability of data and search results in open access, in which it is possible to perceive the change in network dynamics. To the extent that the researcher can draw on new information inputs, ie the research data sets made available by other researchers for analysis, comparison, application and reuse of this data in their own research, using data repositories in the search for these data sets, he will also later have to make available the data he produced in the same repositories, according to numerical indication 2, presented in the researcher's streak. In a traditional scenario, when only bibliographic research was performed (figure 2), in the scenario made possible by open science, the possibility of searching for data alters the researcher's methodology.

To the extent that the data themselves constitute the inputs for secondary analysis and new inferences, they play a greater role, acting on the other actors of the scientific knowledge generation network, who now reorder their research. The intensive generation and availability of data projected a non-human element that until then had been supporting the scientific communication network: research data.

## 6 Final Considerations

Scientific production, and the communication of its results, is a complex, heterogeneous and interdependent process. Understanding the dynamics of these relationships and the consequences of the actions of all actors involved is essential to understand the directions that science production and communication have taken. Although not the exclusive form, open access has been a practice increasingly encouraged by funding agents and the scientific community itself. These are initiatives of the community itself, such as the open source software movement, and then the open access movement to scientific publications that, together with the technical tools and protocols developed by those same communities, have supported the implementation of open access policies and research data sharing. Thus, their reuse can be considered if they are appropriate to the object of study and their collection methods and techniques are documented.

Data have been even more relevant in recent years in the generation of scientific knowledge. Its exponential production, achieved by the availability of information and communication technologies, through the internet, and by large data generation resources, has given it the power to change the dynamics of the network itself. Research data itself is not a new element in the knowledge production process. However, the description of its role, as a way of simplifying complexity, reveals its juxtaposition in relation to other elements, demonstrating its agency that modifies the structure of the network. In other words, research data that was produced and forgotten, disorganized and inaccessible in the personal archives of researchers or institutions, as it is treated, standardized, preserved and freely available, is a new input to make science.

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