THESIS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

Visions and Infrastructures of Open Science

Case studies on how Open Science practices reconfigure existing infrastructures

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Abstract

Open Science practices are shaping both science and policymaking. This thesis examines the visions of Open Science and their enactments through four empirical cases. It provides an understanding of what Open Science means in terms of infrastructures: in cases where Open Science practices exhibit infrastructuring efforts, where they reconfigure existing infrastructures, or where such infrastructuring efforts are not sustained.

In this thesis, the overarching visions of Open Science are identified as participation, public benefit, and transparency, and these visions are interpreted in relation to the erosion of public trust in science, the commercialisation of science, and the replication crisis. Alongside the emergence of these crises, new digital sharing technologies have led to the positioning of Open Science practices, such as open-source software, Citizen Science, and Open Data, as imagined and prescribed solutions to these crises.

Building on this framework, this thesis has four main objectives, each pursued through a case study with its own set of methods: first, it examines infrastructuring efforts in a cluster of published articles to investigate how transparency is prescribed as a solution to the replication crisis through a mixed-methods approach. Second, it examines the limitations of participatory knowledge-making initiatives situated outside science by comparing four citizen observatories through interviews. Third, through retrospective participant observation and document analysis, it addresses policymakers' visions of participation in Tehran and their efforts to improve digital participatory tools. Lastly, it investigates what a public good Open Science might entail by studying the use of open-source tools in a water infrastructure through ethnographic visits and interviews.

This thesis concludes that Open Science practitioners and advocates, aim to enact reform in science and policy through the implementation of Open Science practices. However, relying on technical approaches will not address the changes they aim to achieve. Furthermore, infrastructures play a critical role in enabling or constraining Open Science visions.

Keywords: open science, open data, participation, infrastructure, citizen science, open-source

LIST OF PUBLICATIONS

This thesis is based on the work contained in the following papers:

I. Open Science as an Infrastructure Solution to the Replication Crisis, by Parissa Mokhtabad Amrei and Catharina Landström. Revised and resubmitted to *Minerva* following peer review.

II. Citizen Science without Scientific Infrastructures: Temporal Vulnerabilities of Environmental Citizen Observatories, by Parissa Mokhtabad Amrei. Revised and resubmitted to *Science as Culture* following peer review.

III. Failing to Facilitate the Flow of a Public Infrastructure: A Policymakers' Story of Reporting Tools in Tehran, by Parissa Mokhtabad Amrei. Revised and submitted to *Big Data & Society* following peer review.

IV. Reviving Public Good through Infrastructure: The Case of Open-Source Tools in a Water Infrastructure, by Parissa Mokhtabad Amrei. Submitted to *Journal of the Association for Information Systems*.

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1. Introduction

1.1. What is Open Science?

Open Science became a hype in online discussions driven by individual advocates, policy initiatives, and online communities, particularly after the 2010s, when both grey and academic literature proliferated, emphasizing the importance of sharing, opening research and data, and transparency. Meanwhile, governments and funding bodies began mandating and recommending principles such as the Open and FAIR data principles[1] (Wilkinson et al. 2016), and academic collaborations, online libraries, and repositories were created. The hype generated considerable optimism regarding the potential and benefits of Open Science practices.

The general idea of Open Science in online discussions has centred around the closely connected notions of transparency and openness in the contexts of policy and research. Transparency is associated with the visibility of data or knowledge production processes that are documented, clear, and shared online. Openness is linked to being open and freely accessible to all, and to allowing everyone to contribute (Lyon 2016; Leonelli et al. 2015; Vicente-Saez and Martinez-Fuentes 2018). Open Science has been associated with a type of knowledge that could be corrected through the scrutiny of publics outside universities, made accessible to them, and that could increase trust in science (Rosman et al. 2022), and consequently enable the public to contribute to it. In this context, all these aspects were expected to lead to improvements in science and to benefit society. This idea attracted the interest of various stakeholders such as policymakers, non-governmental organisations, and scientists.

The online discussion is also backed by a critical and intellectual dimension. On this side, the rhetoric of Open Science discussions focuses on making science more democratic (Strasser et al. 2019). It seeks to blur the divisions between scientists and non-scientists, and between science and what falls outside the definition of science. These arguments, as some contend, are reactions to issues and crises such as the commercialisation of science, the lack of public trust in science, and the erosion of the credibility of scientific findings (Sismondo 2017; Wynne 2006; Gauchat 2011; Mirowski 2018).

[1] The FAIR principles say that "all research objects should be Findable, Accessible, Interoperable and Reusable (FAIR) both for machines and for people" (Wilkinson et al. 2016, 3).

In these discussions, Open Science is neither a well-defined nor a singular practice or concept. It is an *umbrella term* (Fecher and Friesike 2013) perceived in many ways and manifested through diverse practices. A literature review has defined Open Science as "transparent and accessible knowledge that is shared and developed through collaborative networks" (Vicente-Saez and Martinez-Fuentes 2018, 428). This definition encapsulates the core tenets of Open Science: transparency, accessibility, sharing, and network building. However, it is too general to clearly demarcate Open Science. Others have defined Open Science through a central notion of openness, common across a diverse array of practices (Fecher and Friesike 2013; M. A. Peters 2013; Lund 2025). The practices encompass, but are not limited to, Open Access, Open Data, open-source software and tools, and Citizen Science, and they collectively offer interconnected promises through accessibility, sharing, and transparency.

Open Access is probably the most familiar practice to scholars because it is through Open Access that the end products of science are made available online (Curry 2018). Open Access has required publishers, as its key actors, to change their business model and practices. Its central promise is to make science available to all and to facilitate scientific dissemination in order to boost scientific progress and to benefit the public (Fecher and Friesike 2013; Phelps et al. 2012; Curry 2018); Open Data can be exercised through governmental and public websites that make datasets available online on the basis of the right to access or their usefulness for citizens or corporations. Alternatively, it is a scientific practice, in which scientists are required to share their scientific data and research procedures online, and this has affected researchers' research processes or at least added extra tasks to them. Within the realm of open government data, motives for data disclosure include transparency, gaining social and commercial value, and the advancement of participatory governance (Attard et al. 2015; Veljković et al. 2014) and within the research domain, data reuse and transparency stand out as primary motivations (Molloy 2011).

Open-source practice emerged from the computer software industry and became popularised with well-known examples of opening the source codes of operating systems such as Linux (Hess 2011). In its initial phase, the open-source movement as part of the hacker ethic is known to resist the commodification of knowledge and challenge the capitalist organization of labour, property, and work (MacKenzie 2001). The open-source concept, with a voluntary and distributed nature (Xiao et al. 2018), centres around the right to access and the promise of benefitting the publics (Baack 2015). Open-source practice engages actors from outside science, and open-source projects may be initiated, maintained, and funded by entities outside

scientific institutions (Leonelli 2023; Schildhauer and Voss 2013; Wehn et al. 2024). This condition forms one of the bases for the ongoing lack of consensus on whether open-source tools and software are part of Open Science practices (Willinsky 2005; Fecher and Friesike 2013). Open repositories and collaboration platforms such as GitHub, which host open-source software, are such actors operating outside scientific institutions. GitHub, now under the ownership of Microsoft[2], serves as one of the largest open repositories where developers share their code and expertise while collaborating with others in the field (Sas et al. 2023). Originally conceived by three individuals, GitHub was established with the goal of providing a platform for developers to contribute to code development in a distributed and open manner. Participants from various backgrounds actively contribute to these open communities (Wachs et al. 2022), whose motivations are sometimes identified as external, such as complying with funding agencies which require them to publish the results in open repositories or personal, such as gaining credibility among developers, or a feeling of satisfaction and a belief in shared knowledge (Lancashire 2005; Lerner and Tirole 2002). Although individuals with academic affiliations may play a significant role in sustaining these communities, their contributions are not tied to their academic associations, nor are their codes legitimised through these ties.

Citizen Science, which is another practice of Open Science that exceeds science institutions, includes numerous cases in which non-scientists take part in data collection and other aspects of the research process for biodiversity, medical knowledge, or environmental pollution monitoring (Bonney et al. 2016; Strasser et al. 2019). Generally, through the recruitment of citizens to do science and by questioning the distinction between experts and lay people, Citizen Science promises a more democratic science and scientific progress (e.g., Strasser et al. 2019; Kasperowski and Kullenberg 2019; Ottinger 2010). Gwen Ottinger (2010) proposes that there are two types of Citizen Science: one that emerges as grassroots initiatives, primarily in response to environmental or medical concerns, and another that is established by private or public institutions. Initiatives originating from grassroots movements, which might aim for social justice or political change, may draw upon scientific expertise in their methodologies, standards, and networks, yet they remain situated outside formal science institutions, and their endeavours are not explicitly framed within scientific projects (Mahr and Dickel 2019; Strasser et al. 2019), although they can still impact scientific research.

[2] https://www.globaldata.com/company-profile/github-inc/ [retrieved in April 2025]

The practices of Open Science, enabled through networks and digital infrastructures on one hand and facilitated by policies and funding allocations (Leonelli 2023, 2), belong to both the physical-material and political/intellectual worlds. This means that while some frame Open Science as more of a policy object (Lund 2025) which makes it belong to the political world, Open Science practices are materialised as part of the configurations of digital platforms, data centres, and generally ICT networks of actors. In some cases, they are constituted more by anticipatory expectations and visions, which shape the practices in a future-oriented manner, and in other cases, they involve data infrastructures and established networks.

From a science studies perspective, it is argued that Open Science is intertwined with a particular mode of science governance which promises changes in the current state of science such as being more reproducible (Leonelli 2023, 2022; Romero 2019), democratic, and transparent (Levin et al. 2016). For instance, within the field of Genetically Modified Foods, Irwin (2006) views openness as symptomatic of the science-society relationship, suggesting a crisis in legitimacy and trust. According to Irwin, the lack of public trust poses a significant concern for current scientific governance, and thus openness and transparency should be seen as solutions addressing this issue (Irwin 2006, 305). Similarly, Rosman and others (2022) propose two mechanisms for the relation between public trust and Open Science practices, one at the level of science where the adoption of Open Science practices reduces malpractices in science by increasing transparency and replicability and a second mechanism where Open Science practices can be perceived by the public as an indicator of trustworthy science (Rosman et al. 2022, 1047–48). In other instances, Open Science has been highlighted as "an aspect of an emergent global science system" which refers to "open governance, and democratised engagement and control of science by scientists and other users" (Peters 2010:105-106). In this global governance, EU agencies are also identified as pivotal actors advocating for openness and public engagement in science. They have created and funded projects such as Horizon 2020 and Horizon Europe, advocating for licences such as Creative Commons' CC BY-licence, and generally setting Open Science visions and policies leading to the promotion of Open Science repositories, platforms, and initiatives (Leonelli 2023; Lund 2025).

In this thesis, I argue that Open Science, as part of a new form of governance in science, is a response to perceived dysfunctionalities and deviations from ideal norms of science. Scholars identify these deviations as being closed, non-democratic, non-replicable, and commercial, or benefitting only limited groups (Lave et al. 2010; Mirowski and Sent 2002). Open Science practices, which reach beyond the borders of science and might blur the division between the

scientist and the layperson, are enabled through digital technologies and are proposed as solutions to the deviations and dysfunctionalities, as well as agents of change towards ideal norms of science. The envisioned changes by Open Science impact scientific practices, rendering them visible to both internal and external moral scrutiny. Through data-sharing mandates, Open Science encourages or obliges scientists to undertake managerial tasks and checklists and to intensify the use of platforms and online repositories (Penders 2022).

Moreover, this new governance, by blurring distinctions, reshapes the agenda and practices of science as well as addressing the very central role and function of science in society, which is to produce credible and legitimate knowledge (Sismondo 2017). If credible and legitimate knowledge can be produced outside science and by non-scientists, the existence of science as an institution is called into question.

This thesis regards Open Science as part of the new governance of science and as both a set of conceptual terms and an object of study. It approaches it on two analytical levels: visions, promises, wishful thinking, agendas, policies, documents, and academic literature that are advocated by various academic, civil, and policy-making actors; and practices that are enabled through digital sharing technologies, showing infrastructuring traits or functioning as infrastructures of Open Science, such as open-source repositories or open access infrastructures. These two levels, although they shape each other and, due to their sociomaterial character, are not easily distinguishable from one another, operate on different temporalities. The first level introduces changes in science and policy and is oriented towards the future(s) in which these changes are happening. In the second level, the technologies, badges, shared knowledge, and data become or have become embedded in scientific practices and infrastructures.

With this understanding of Open Science, I aim to critically analyse it and examine how it aims to enact changes in scientific practices and boundaries and how it reconfigures existing infrastructures.

In this dissertation, I explore Open Science cases in various contexts of academic literature, environmental participation, policymaking, and the public sector by developing an infrastructural lens. I focus on the core visions of each Open Science practice described in the case studies in this thesis and investigate how these visions are enacted in interplay with existing infrastructures such as scientific infrastructures. In the four case studies, I am

interested in examining whether these visions address the perceived issues or serve merely as technical fixes within the broader shift towards digitalisation.

1.2. Research Questions and Outline of the Thesis

The overarching research questions of this thesis are:

What can the concept of infrastructure contribute to understanding Open Science practices and the enactment of its visions? How are Open Science visions enacted and how do they reconfigure scientific practices?

Then, with respect to each vision, I ask case-specific research questions:

1. How is Open Science expected to reconfigure scientific practices within a specific scientific field?
2. What are the limitations of participatory knowledge-making initiatives situated outside of science?
3. How are visions of democratic participation enacted from a policymaker's perspective and what are the barriers to this vision?
4. Under what sociomaterial configurations and relations do Open Science practices benefit publics?

The first case in my PhD thesis, co-authored with Catharina Landström, is a mixed-method investigation of visions of Open Science in a cluster of published articles between 2017-2021, mostly in behavioural science, which shows infrastructuring efforts for the implementation of Open Science as a solution to the replication crisis. The second case compares four examples of environmental citizen observatory initiatives in Europe which are situated outside science. The study argues that Citizen Science initiatives outside science face temporal and structural vulnerabilities due to the lack of ties to infrastructures such as scientific infrastructures. The third study examines a case of Open Data in relation to two urban participatory tools in Tehran from a policymaking perspective. Through a retrospective reconstruction of narratives and activities based on reports, notes, and data, it investigates the efforts to open the data of the two tools in Tehran and to improve them in order to enhance public participation. The research asks why the vision of transparency did not lead to sustained improvements in public participation. It concludes that the focus on practice-level alignment work through digitalisation overlooked the infrastructural issues. The last study examines the use of open-source tools in the water and waste infrastructure of a Scandinavian city for leakage detection. It illustrates an example

where the use of open-source tools in an infrastructure can be a manifestation of Open Science as a public good. The four cases foreground the changes that Open Science aims to bring through the promises associated with each problematic state of science or governance regarding credibility, legitimacy, and its benefits to the publics. The analysis further traces how these cases are variously enacted, showing infrastructuring efforts, reconfiguring scientific practices and existing infrastructures.

Open Science is conceptualised in the four cases as a reconfiguring force or as part of a reform movement for scientific (Penders 2022; Peterson and Panofsky 2023) and policy (Lund 2025) practices, reshaping the science-society-policy relationship. This angle makes Open Science a significant subject from a science studies point of view.

The rest of the introduction is followed by a brief explanation of Open Science practices. Then, the philosophical and intellectual roots of Open Science are explored. The second chapter is a theoretical chapter, which begins with a discussion of the concept of infrastructure, explains how this lens has strengthened this thesis, and argues why Open Science is better understood through an infrastructural lens. The third chapter reviews the overall visions of Open Science practices, such as the promise of openness, visions of participation, scientific progress, and the idea of Open Science benefitting the publics. I connect each vision to a perceived crisis or recognised problem in science and policy, for which Open Science is envisioned as a response. The fourth chapter discusses the methods used to study Open Science practices and answer the research questions. Then, after a brief summary of each of the empirical cases, the thesis concludes. At the end of this text, the four papers of this thesis are included.

1.3. Open Science Practices

As mentioned, the umbrella of Open Science as a concept involves ambiguities and the term *science* within it is not precise. A brief overview of the practices can help illuminate these ambiguities. In the following paragraphs, Open Access, open-source tool and software, Open Data, and Citizen Science as main practices of Open Science will be reviewed.

Among the practices, Open Access is associated with sets of tools, networks, and policies primarily in scholarly communication, aimed at ensuring that research outputs are freely accessible to readers. Curry (2018) traces the roots of Open Access to two origins: one stemming from psychologist Steven Harnad’s 1994 proposal advocating for the "free electronic dissemination of research results", and the other emerging from the Budapest Open Access Initiative in 2002, which described open access as "free availability on the public internet,

permitting any users to read, download, copy, distribute, print, search, … without financial, legal, or technical barriers" (Chan et al. 2010, as quoted by Curry 2018: 35). By the 2010s, open access had become a politically salient issue in the UK and elsewhere, with the prevailing notion asserting that taxpayers deserve access to the results of scientific research (Curry 2018, 35–36).

Open-source software denotes open and free access to the "blueprint of a product" (Watson 2015, 2) or, metaphorically, a recipe for a product (McInerney 2009). The open-source movement emerged as a form of resistance to proprietary information science during the 1980s and 1990s (MacKenzie 2001, 543) and relies on voluntary participation in the development of software source codes (Weber 2004, 62). By definition, software achieves open status "when it is freely distributed and its internal workings are not hidden, black-boxed, or private" (MacKenzie 2001, 541). The open-source movement is concerned with the right to access and distribute knowledge (Baack 2015) and is recognized as one of the primary influences on the Open Data movement as well (Baack 2015).

Open Data is understood to be generated by governmental agencies or publicly funded research projects (Kitchin 2014, 48). The Open Data movement has sought to broaden access to data, guided by principles of openness, participation, and collaboration. In his delineation of Open Data, Kitchin (2014) employs Pollock's formulation: "Data is open if anyone is free to use, reuse, and redistribute it" (Pollock 2006 as cited by Kitchin 2014, 49). Open Data represents an Open Science practice that has already been incorporated into laws and regulations in various countries, and it includes both quantitative and qualitative types of data.

Citizen Science is a practice tied to the participatory turn in science and is defined as the "involvement of non-scientists in science" (Kullenberg and Kasperowski 2016, 2). Indeed, Citizen Science has been conceptualised within broader traditions of public participation in science rather than exclusively as an Open Science practice (Macq et al. 2020; Strasser et al. 2019) associated with openness, access, and transparency. However, many in both the policy domain (European Citizen Science Association (ECSA), n.d.) and research emphasise the overlap between Citizen Science and Open Science (Fecher and Friesike 2013). Proponents argue that Citizen Science holds the potential to democratise and open epistemic roles, as well as broaden access to knowledge production among interested members of publics, aligning it with the promises of other Open Science practices. Citizen Science initiatives exhibit diverse forms of activities, reach, and epistemic focus (Schrögel and Kolleck 2019). For example, in

some projects, citizens may participate in novel experimental approaches to knowledge production, while in others, citizens are primarily engaged in data collection, for example by capturing photos using smartphones and subsequently uploading them to Citizen Science applications. Moreover, these projects may take the form of grassroots networks or organisations, which emerge in response to environmental concerns, or may be initiated by public and private institutions to address specific objectives.

In addition, even if we equate the broader term of knowledge with science, which can be described as a socially organised practice or as an institution (Latour et al. 2013; Merton 1973), in some Open Science practices, namely Open Data and open-source software, knowledge may not exist in its traditional form, meaning that it may not be recognised as knowledge, may lack contextual grounding or empirical basis, and may not necessarily entail thought processes or belief systems. Rather, what is shared consists of datasets composed of numerical entries in the case of Open Data and computational code in the case of open-source software and tools. Therefore, the term *science* under the umbrella of Open Science is neither comprehensive nor conclusive.

1.4. Historical and philosophical roots of Open science

One question about Open Science practices is whether they are rooted in the intellectual and philosophical traditions of science or whether they envision a rupture with existing practices. This section addresses this question by dividing the discussion of the historical and intellectual origins of Open Science into two parts. First, it examines the works of scholars who have investigated the characteristics of science, such as openness, in 16th- and 17th- century Europe. Second, it explores the ideas that Open Science practitioners and advocates primarily draw upon from the 1940s as the intellectual foundations of Open Science.

1.4.1. Historical discussions on modern science in the 16th and 17th centuries

The term *Open Science* began to appear in academic journals in the 1980s. By 2025, the number of articles on Open Science had exceeded ten thousand across various disciplines[3]. However, scholars argue that Open Science values, such as openness, sharing, and transparency in science, had long existed prior to the 1980s.

Shapin and Schaffer, in their book, Leviathan *and the Air-pump* (1985) portray two rival models of science coexisting in 17th-century England. They argue that one, represented by Robert

[3] Search in Scopus and Web of science in August 2025.

Boyle, was experimental and communal, while the other, represented by Thomas Hobbes, was deductive and authoritarian. The authors claim that, of the two, Boyle's experimental model became institutionalised, whereas Hobbes's vision failed to take hold (Shapin and Schaffer 1991). The experimental model, in their view, was aligned with the political order of the era and was publicly witnessed and socially trusted through processes of exhibition. Their historical account implies that science at the time involved transparency and openness, albeit limited to selected groups of publics.

Other scholars have identified a similar historical trajectory in modern science. David (2004) and Vermeir and Margócsy (2012) conceptualise the history of Open Science as coextensive with the history of modern science and identify a continuity in both the notions and applications of Open Science throughout the history of modern science (M. A. Peters 2013).

David has situated the emergence of Open Science within a functionalist economics framework in the historical context of Renaissance Europe (David 2004, 571). He argues that openness and disclosure have served as the foundation for the cooperative, cumulative generation of predictability and reliability of knowledge and proposes that the norms of Open Science have persisted in science from the late 16th century to the present. He identifies Open Science as originating from the ornamental patronage system in Europe, which involved peer experts, exhibitions, and other collective events, noting that in the post-1660s era, many academies and private institutions were established. Based on a historical analysis, he concludes that openness became a necessity, as it facilitated the rapid validation of findings, reduced duplication of research efforts, and expanded the scope of complementarities and beneficial spillovers among research programs (David 2004, 576). Additionally, he suggests that the sociopolitical matrix of actors also contributed to the historical formation of the key ethos and organizational structure of Open Science (David 2004, 582–85).

1.4.2. Perceived Intellectual roots of Open Science

In the 1940s, two influential books were published which are considered the intellectual foundations of Open Science: the first, *The Normative Structure of Science* (1942) by Robert Merton, articulated the ethos of science, while the second, *The Open Society and Its Enemies* by Karl Popper, was published three years later. The ideas from these two scholars remain central to contemporary debates on openness in science (Leonelli 2023; Mirowski 2018; M. A. Peters 2010).

What is often emphasised by proponents of Open Science, particularly within the behavioural and natural sciences, is that Open Science represents a revival or enactment of Mertonian norms (Merton 1973; David 2004). Merton introduced a set of prominent norms and ethos governing science and its participants. According to him, the ethos of modern science is shaped by four institutional imperatives: Communism, Universalism, Disinterestedness, and Organized Scepticism. Drawing on these Mertonian norms, proponents of Open Science claim that the Open Science agenda is "built on shared principles of science" (Dienlin et al. 2021, 16). They argue that Open Science practices align with the societal roles of scientists. From this perspective, digital technologies are viewed as enabling Mertonian norms to "find expression" (Chesbrough 2015, 6), and what is perceived as Open Science in policy, research, and academic institutions shares its roots with Mertonian norms (David 2004).

However, the connection between Mertonian norms and Open Science principles of transparency and openness is not straightforward. In the context of the philosophy of Open Science, Leonelli (2023) examines Merton's emphasis on the role of institutions in demarcating relevant scientific expertise from irrelevant non-scientific expertise. Mertonian ideas about science pertain to norms within the scientific realm, and this framing establishes a separation between science and society by accentuating the institutional role of science. In this sense, although Mertonian ideas are reinterpreted to fit Open Science principles, they do not correspond to the notion of Open science as a democratising and more engaged approach to science governance.

Another foundational idea for Open Science is attributed to Popper's views on the "open society" which were published a few years after Merton's book (M. A. Peters 2020; Leonelli 2023). In his perspective, democratic institutions set ground rules for rational arguments and credible evidence. Popper used "openness" to denote the freedom to exercise judgment and to reflect on the ground rules set by institutions (Leonelli 2023, 11). He exemplified science as a model institution for democratic societies: one that other parts of society could follow in its rationality, evidence-based credibility, and openness to foster democracy. Two decades later, in his book *Conjectures and Refutations* (1963), he emphasized that a claim is only scientific if it is open to being checked and refuted by others.

Diverging from this logic, proponents of Open Science in the natural and behavioural sciences, inspired by Popper's ideas, seek to improve science through the Open Science agenda and its principles of transparency and openness (Leonelli 2023; Mirowski 2018; M. A. Peters 2010).

However, these proponents do not necessarily adhere to Popper's portrayal of science as an existing model for society or his understanding of the science-society relationship. Rather, they envision achieving such a model through the implementation of Open Science practices.

The second significant connection between the philosophical roots of Open Science and Popper's ideas was sparked by the *Replication crisis* in behavioural sciences (e.g., Nosek et al. 2022; Archer 2024; Earp 2016; Freese and Peterson 2017; Rubin 2025; Derksen 2019; Romero 2019). Open Science advocates drew on Popper's discussion of reproducibility in *The logic of scientific discovery* (1959), in which he argues that single occurrences in science have no significance (Leonelli 2023; Romero 2019; Popper 2005). The crisis gained widespread recognition when attempts to replicate certain well-known research findings in the field failed (Open Science Collaboration 2015). In response, scholars in the behavioural sciences sought to strengthen credibility by adopting Open Science guidelines and principles. This prominent debate will be discussed in detail in the subsequent section of the thesis[4].

Overall, the discussion on the historical and intellectual roots of Open Science emphasises both the rupture and the continuity of Open Science from the past to the present. On one hand, David (2004) and Shapin and Schaffer (1991) imply a form of openness and transparency that existed at the time of the emergence of modern science. On the other hand, references to Kuhn and Popper by Open Science advocates suggest a more prescriptive approach to Open Science practices.

In Shapin's and Schaffer's, and David's approach, observations of openness and transparency suggest that the ideas of Open Science can be traced back to the early era of modern science. However, Open Science ideas and practices can hardly be separated from their material and infrastructural contexts: it is important to note that scientific practices, the infrastructures of knowledge production, and the sociomaterial configuration of science today prevent us from equating concepts such as openness and transparency in that period with Open Science in the present era. Hence, especially in the case of David, the historical account shows, above all, a reinterpretation of Open Science in light of historical developments. Moreover, Kuhn's and Popper's ideas on the norms of science are interpreted and reconstructed to align with the perspective of Open Science practitioners and advocates.

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[4] Additionally, Open Science is also understood by philosophers to have roots in the works of Kuhn, Wittgenstein and several other philosophers of science; however, these connections have not been acknowledged by scholars in other fields, such as the natural and behavioral sciences (Leonelli 2023; M. A. Peters 2020).

This is because digital technologies and digital knowledge infrastructures have radically changed scientific practices, and the current Open Science practices have been enabled and widely disseminated through them as their core sociomaterial conditions. Practices such as Open Data sharing, collaborative platforms, Open Access, and open-source software depend on repositories, data centres, and platforms that did not exist in earlier periods, making it difficult to meaningfully compare these practices with past forms of openness in science. Indeed, with the exception of Citizen Science, most of these practices would have been unfeasible without digital technologies; nonetheless, even Citizen Science has benefitted significantly from them in terms of accessibility, the scale of data collection, the feasibility of collaboration, and affordability.

The claim of historical continuity of Open Science therefore overlooks its dependence on digital technologies and consequently ignores the material constituents of Open Science practices. It risks reducing Open Science to abstract ideas of openness and participation, as if it has existed through centuries regardless of material potentials and conditions.

2. Infrastructures and Open Science: a theoretical focus

Developing an infrastructural lens has provided a unique perspective for this PhD thesis in understanding Open Science practices and the ways in which their visions are enacted. This perspective draws on both the infrastructure studies tradition within STS and how its characteristics are conceptualised and understood, as well as on Open Science practices and values, which are situated within science-society relations.

Scholars in STS infrastructure studies such as Susan Leigh Star and Paul Edwards have conceptualised infrastructures as sociotechnical complexes upon which societies depend (Star 1999; P. N. Edwards 2003). Infrastructures have also been linked to ideas of the public (P. N. Edwards 2003) and described as largely invisible entities that become visible primarily through moments of breakdown (Star 1999). Infrastructures, with their embedded standards, enable the flow of information, ideas, and materials (Larkin 2013). They are conceptualised across scales: from the macro-level to the micro-level, from established sociomaterial entities providing a sense of stability (P. N. Edwards 2003) to unfinished systems that manifest ongoing processes of classifications and standardisation in the form of *infrastructuring* (Nost 2022; Blok et al. 2016; Morita 2016; Michael 2020).

2.1. Sociomaterial Complexes

Importantly, infrastructures are sociomaterial, not merely digital technologies. They include organisations and "socially communicated background knowledge" (P. N. Edwards 2003, 3). The sociomaterial characteristic of infrastructures, although it might seem self-evident to researchers in anthropology, STS, or geography, is of crucial importance. In the fields of engineering and information systems, infrastructures, due to their visible technical and material components, are often framed by experts and scientists as merely technical. However, this framing is not sufficient for delineating the boundaries of infrastructure as an object of study in STS because it overlooks their social dimensions.

If an infrastructure breaks down, this is a result of a combination of human alignment work and practices, political and economic contexts, institutions, policies, and regulations, as well as technical aspects and emerging technologies. On the other hand, if an infrastructure operates smoothly, it means that its technical systems are well aligned with social and economic contexts, and a great deal of hidden and invisible work is being performed. Hence, as Edwards (2003) mentions, there is no mere human error or technological failure in infrastructures.

Understanding infrastructure as sociomaterial provides an opportunity to study Open Science without mistaking access to the technologies and tools of knowledge infrastructures for *the* infrastructures themselves, or assuming that transferring technologies will result in the transfer of infrastructures. For example, this can be the case with citizen science communities, which have access to data collection and data processing tools but lack established infrastructures.

In this thesis, it is argued that infrastructure studies can benefit from refocusing on both the narratives and the functionality of infrastructures. These two cannot be separated. While the narratives refer to how infrastructures are understood, perceived, and presented, functionality refers to the actual provision of services, the flow of goods, information, and knowledge, and generally the teleological aspect of infrastructures. Studying only narratives undermines the sociomaterial character of infrastructure. It is only in relation to the material and technical aspects of infrastructures, that narratives, or here in my case, visions can be understood. In other words, while politics, poetics, narratives, and visions of infrastructure effectively illustrate the broader discourse governing those infrastructures, they do not address the functionality of the infrastructures or the question of for whom the infrastructure works.

2.2. Infrastructuring vs. Infrastructures

Another idea emphasised in this thesis is that infrastructures extend beyond the notion of a network. In some STS traditions, namely the STS tradition of ANT (Actor-Network Theory) and post-ANT, infrastructures and networks are not ontologically different. This is because *networks* are constituting the world. In ANT, for example, it is through the relational ontology of networked actants that the world is constituted (e.g, Law 2013; Latour 2005). This view, although very helpful at the methodological level for this PhD thesis, is not sufficient to explain vulnerabilities in digital networks and changes in infrastructures. I argue in the present thesis that networks and infrastructures have different temporalities. Infrastructures, although consisting of various networks, operate on a historical temporality (Van Der Vleuten and Kaijser 2005). Moreover, even though networks have similar characteristics to infrastructures in their attempts to make classifications and standardisations, they face temporal vulnerabilities when compared with infrastructures. This view is a contested one in STS, particularly among scholars arguing that infrastructures are fluid, incomplete, becoming, and heterogeneous (e.g., Lemanski 2020; Guma 2025; Lawhon et al. 2023). I will discuss this further in the conclusion section.

In the context of Open Science, some initiatives, have already evolved into infrastructure, while others consist of future-oriented policies, visions, and guidelines that imagine the future infrastructuring of those practices. In certain Open Science practices, visions have led to the creation of policies aimed at implementing Open Science, networks that enable sharing, standards and guidelines for sharing, as well as the involvement of experts who facilitate and validate data. Through these processes, networks expand, standards are established, and repositories are provided to improve the flow of information. Thus, each network considered to fall under the umbrella of Open Science might be at a different stage in its process of infrastructuring. For instance, Open Access services for libraries and universities are relatively well-established, operating in the background and often invisible to their users. Conversely, policies related to open data and data sharing standards exhibit diversity, and Open Data portals may still be in the early visionary phases.

While these infrastructuring attempts are present in the Open Science practices studied in this thesis, the focus is on their temporal dynamics, as well as the vulnerabilities and limitations of these networks. This emphasis draws a contrast between temporary, failed and transient networks and established infrastructures.

2.3. Standardisation, Democratisation and Practice Level

Infrastructures are described as embodying standards (Star 1999, 381). Standardisation and classification prevent us from inventing practices and routines every time and facilitate the sharing of information and goods within infrastructures. Some claim that standardisation is the key process in infrastructuring (Star 1999; Bowker and Star 1999).

Each Open Science practice that enables participation, collaboration, contribution, and online free access requires a form of standardisation. This means that common file formats, applications, and platforms are needed. Hence, sharing requires standardisation. Moreover, democratisation, as one of the central values and visions of Open Science, requires sharing. As Mackenzie and others (2013) rightly note, within standards there exists a norm of democratisation. Open Science practices, if they pursue knowledge sharing and the democratisation of knowledge, require standardisation. This brings Open Science and the concept of infrastructure in STS into a very close relationship. However, although standardisation may signify infrastructuring, it does not equate to infrastructure. This means that standardisation can occur at the level of *practice* (the micro-level), forming networks without necessarily leading to stable infrastructure. Standardisation at the level of practice,

meaning common file formats, protocols, indicators, procedures, and platforms, can align actors and enable the flow of knowledge and goods, as well as support institutional stability, maintenance, and the establishment of an installed base. In other words, actors may adopt common standards provisionally, forming networks for collaboration, yet remain contingent and vulnerable rather than being consolidated through institutional governance, mechanisms for establishing credibility, funding, and support structures.

The infrastructure lens, as I interpret Edwards's (2003) note, can bridge the micro, meso, and macro levels, as infrastructure itself operates and function on various scales. This means that the infrastructure lens can attend to how infrastructures are collectively shaped and interrelated. It also contextualises standardisation, infrastructuring efforts, alignment work, and infrastructural changes within broader societal transformations.

Despite these strengths, the *practice turn* in infrastructure, in Edwards's articulation (2003), with its constructivist approach, lacks a meso-perspective, or an analysis of how specific infrastructuring processes interact with other infrastructures and how they reconfigure and reshape them. Whether Open Science bears the danger of destabilising existing knowledge infrastructures or consolidating them is yet to be seen in empirical cases. With only a constructivist approach and practice-based lens, this question cannot be answered. Such limitations become even more crucial in the era of infrastructural decay (Silver 2021), when formerly public good infrastructures are privatised and no longer function for the population they once served (Plantin et al. 2018).

2.4. The *public* in infrastructure studies

One of the key traits for understanding infrastructures in societies is their relation to the notion of *public* (P. N. Edwards 2003; Plantin et al. 2018) in terms of serving the public interest, being publicly funded, or providing essential public services. This relation is supported by the argument that infrastructures provide critical services to residents or citizens and that they shape the relationship between citizens and the state.

However, this trait is blurred by the ever-increasing involvement of the private sector in infrastructures (Van Der Vleuten and Kaijser 2005). As wider political-economic changes have reformulated accountability, ownership, management, and maintenance of infrastructures around the world, the public aspect of infrastructure has become less apparent and less emphasised.

Relevant STS literature formulates the relations between the notions of public and infrastructure from a completely different perspective. It focuses on how infrastructures *constitute* publics (Hetherington and Jalbert 2023; Michael 2020; Green et al. 2025; Koo 2024). From a constructivist approach, the public is constituted, evoked, or represented through narratives, policies, technologies, and affective events. In this approach, the public is not pre-given or pre-existing. In other words, the constructivist approach in STS does not recognise a higher entity in the ontological hierarchy called the public.

Therefore, the view that infrastructures involve some public essence is not widely supported in the STS literature and does not fully align with the constructivist approach of the STS tradition in studying infrastructures. Yet, the public aspect of infrastructure has been a driver for studying infrastructure and for making it a matter of concern for STS scholars. This can be clearly observed in studies of energy infrastructures (Cotton and Devine-Wright 2012; Green et al. 2025; Velkova 2016), railroad infrastructures (Haikola and Anshelm 2022), and water infrastructures (Blomkvist et al. 2023; Michael 2020; Hetherington and Jalbert 2023; H. Peters and Landström 2022), to name a few. The studies manifest a tension that exists between infrastructures as providers of essential services in a collective way, and the individualised or networked responses to inhabitants' needs in increasingly privatised and commercialised contexts. In other words, foregrounding the notion of *public* in infrastructure studies can revive attention to the functionality of collective practices.

2.5. Contribution to Infrastructure studies and how to study infrastructures

In conclusion, the argument of this thesis regarding infrastructure and its contribution to infrastructure studies can be summarised as follows: firstly, given the sociomaterial character of infrastructures, both their visions and how they function materially should be emphasised when studying infrastructure. Secondly, the distinction between networks that display infrastructuring traits and established infrastructures is crucial for understanding durability and vulnerabilities in cases involving digital technologies. Thirdly, although digital sharing technologies involve standardisation, they may remain transient and unstable, since standardisation might occur only at the practice level. Finally, the notion of *public* is inherent in infrastructure, which can re-emphasise the functionality of infrastructures.

During my empirical studies on Open Science and following STS literature on studying technology, it became evident that Open Science is not only communication technologies and data management practices. Rather, it encompasses a diverse array of stakeholders, including

experts, scientists, policymakers, communities, funding agencies, and numerous other heterogeneous entities, and it interacts with existing infrastructures. These entities contribute to the establishment of Open Science practices and the enactment of their visions. Sometimes, they are temporary, isolated, and not standardised. In other cases, they consist of standards, routines, and procedures for sharing knowledge in digital infrastructures, and they are well-established.

While some have established infrastructures that operate alongside other existing knowledge infrastructures, others are in the process of infrastructuring (Blok et al. 2016; Karasti and Blomberg 2018; Nost 2022). Therefore, the point is not to see Open Science always as finished infrastructures, but rather to have an infrastructure lens contribute to identifying classifications, standardisations, conventions of practices at the micro level, and their existing relationship with other infrastructures on the meso-level. Therefore, Open Science is neither singular nor a coherent infrastructure. Rather, Open Science is fragmented. Indeed, some of the practices of under the umbrella of Open Science do not have much in common other than digital sharing technologies.

Developing an infrastructure lens for studying Open Science can provide us with a broader perspective from which to understand how Open Science practices are forming networks or getting infrastructured, their temporalities, how they reconfigure other existing infrastructures, and how they function within other infrastructures.

3. Empirical studies on Open Science: Temporalities and Visions of Open Science

While we briefly reviewed the perspective claiming that the historical and intellectual roots of Open Science precede the advent of digital technologies (Vicente-Saez and Martinez-Fuentes 2018), a more prevalent view is that Open Science in its current forms, practices, and ethics of science governance, constitutes an "unprecedented feature of the scientific venture" (Lahti et al. 2017, 3). This viewpoint rejects the notion of continuity between past and present with respect to Open Science, interprets current Open Science discourse as heavily shaped by the emergence of digital technologies, and argues that sharing technologies have transformed the nature and practice of science (M. A. Peters 2010, 106).

One argument supporting this view emphasises the impossibility of practising Open Science without digital technologies. For instance, it is difficult to envision Open Data practices in paper form, as a datasheet in physical format may not be easily accessible or usable by others. Similarly, collaborations among scientists across vast geographical areas, involving the sharing of the research process, would be nearly impossible without digital sharing technologies. Nonetheless, there are a few exceptions, such as well-documented birdwatching citizen science initiatives, which trace back to the pre-digital age (Irwin 2015).

An examination of the literature and policies of Open Science (e.g., Fecher and Friesike 2013; Chesbrough 2015; Holbrook 2019; Molloy 2011), reveals that Open Science is full of promises and visions. It is oriented towards the future, imagining a landscape, in which Open Science practices have contributed to transformations in science, policymaking, industry, and other sectors.

Borup and others (2006) propose that most technological innovations are future-oriented. They argue that innovations aim to "create opportunities and capabilities" (Borup et al. 2006, 285). In their view, future-oriented abstractions serve as tools for analysts and scholars to assess innovations. Following this reasoning, Open Science, if considered as a set of innovative tools, practices, and procedures, is no exception.

Open Science proponents develop their future-oriented abstractions by taking issues in current scientific culture and institutions, such as commercialisation, irreproducibility of research, public distrust in science, and the post-truth crisis as their starting points (Mirowski 2018). From these concerns, they conceptualise visions aimed at addressing and overcoming these

challenges. These visions create links between the science studies literature, which examines the conditions of science, and the Open Science literature, which articulates visions for scientific policies and practices. Consequently, the following review engages with literature focusing on Open Science and relevant discussions within science studies.

While the visions vary among different actors and practices, the overarching visions of Open Science encompass transparency, replicability, public benefit, scientific progress, and democratic participation.

3.1. Vision of democratic Participation and post-truth condition

Social and political scientists have expressed concern about the post-truth era, in which facts and fictions are indistinguishable, and new configurations of practices, epistemic politics, and institutions have emerged (Sismondo 2017). This era is characterised by public distrust in science, in a context where science loses its legitimacy as a source of credible facts.

In response to public distrust in science, both the public understanding of science and public participation in science have been prescribed and encouraged (Wynne 2006). The public understanding of science approach aims to improve scientific literacy through public outreach, based on the idea that as the public gains more knowledge and understanding of science, they will develop greater trust in scientists and their expertise (Koo 2024, 1019). A progressive version of this view advocates public participation in science, which problematises the division between laypeople and experts and calls for the inclusion of non-experts in the production of knowledge (Evans and Plows 2007).

Strongly echoed in Open Science, this democratic participation vision advocates closing the gap between science and society (Holbrook 2019) and imagines a form of science that is participatory, democratic, and accessible to all. The Citizen Science tradition has sought to include citizens in nearly all stages of research, and some scholars and research policy actors argue that through democratisation and public participation in science, new epistemologies are created, experimental methods are introduced, narrow scientific interests can be broadened, and trust in science will be regained (Mahr and Dickel 2019; Ottinger 2022).

In the case of Open Access and Open Data, the democratic vision has been translated into providing online access through scientific publications and online platforms. In the field of research, some scholars see a positive effect of Open Science practices on increasing trust in

science. They argue that visibility and transparency increase trust and that researchers will avoid malpractices of science as a result of transparent and open practices in science (Rosman et al. 2022).

The democratic vision for open governmental data, public sector open data, and open-source software and code, approaches knowledge production slightly differently. With opening data and codes, the vision aims for individuals, institutions, or private entities to utilise them. So, the democratic vision here means access and transparency for all to whom the data and knowledge can be useful.

Open Science practices' influence on trust is neither homogenous nor very promising. In addition, public participation is criticised from various perspectives. Landström (2019) questions the creation of parallel structures for knowledge production, which may occur instead of improving the existing ones, and Hayden (2007, 732) argues that public participation initiatives are often performative rather than substantive, describing them as a carnival. It is also suggested that trust develops from integrity, transparency, and responsiveness (Wynne 2006), and that participation might not be an adequate response to a lack of trust. Other scholars argue that the crisis of public trust in science is linked to residual realist assumptions about participation and publics, and they propose reframing participation as constitutive of technoscience and democracy (Chilvers and Kearnes 2015). Finally, from a broader perspective, Sismondo (2017) argues that participation does not lead to epistemic democratisation and that addressing democratisation requires tackling inequitable political economies of knowledge.

Ironically, some scholars also regard the post-truth era as a consequence of the universalisation of the symmetry principle[5] and the "outcome of greater epistemic democracy" (Fuller 2016). Others have illustrated that involving non-experts in science can make publics more suspicious of scientific results (Wynne 2006). It is even further argued that the democratic participation vision, by conducting science outside science and blurring the distinction between experts and lay-people, may lead to a form of de-infrastructuralisation, or, as Sismondo characterises the post-truth era, to " blowing knowledge structures" (Sismondo 2017).

The stances towards the relation between participation and trust seem rather inconclusive. What can be concluded though is that in many instances, participation has become part of a formal

[5] To put it in simple words, the symmetry principle (Bloor 1991) argues for a symmetrical explanation of knowledge whether beliefs are true or false, or rational or irrational beliefs.

policy object, representing limited groups of people as the public. Further empirical investigations into the quality of these participations are required to grasp what participation does to trust, power asymmetries, and existing infrastructures of science and policy. Nonetheless, it is important to note that some are advocates of participation through Citizen Science, Open Data, and Open Access as a means of increasing public trust through digital platforms and online transparency.

3.2. Visions of transparency and replicability crisis

Another cause of concern in science is known as the Replication crisis, widely recognised in the 2010s. One of the main drivers for this perceived crisis was that important published findings in the social, behavioural and biomedical sciences failed to be replicated (Open Science Collaboration 2015; Romero 2019).

Replicability is considered one of the basic foundations for scientific credibility (Nosek et al. 2022). The replication crisis, similar to the post-truth condition, threatens the epistemic authority of science (Romero 2019), as, following the Popperian framework, science cannot be trusted if experiments cannot be replicated under the same conditions. Therefore, the replication crisis has undermined scientific credibility (Romero 2019, 1), forcing scientists, as the main stakeholders, to revise their scientific practices.

An important solution to overcome statistical and methodological causes of the replicability crisis has been the adoption of Open Science practices (Nosek et al. 2022; Open Science Collaboration 2015; Romero 2019). The practices, with the central vision of transparency, include sharing research workflows and data (Romero 2019, 4) and have been encouraged through policies such as journal requirement and communities such as the Open Science Collaboration.

The replication crisis highlights a perceived limitation in experimental sciences undermining the credibility and epistemic authority of science. The crisis has acted as a catalyst for reform and change in science (Penders 2022). The growing adoption of Open Science practices which changes scientific practices by incorporating preregistration and transparency of research data and procedure represents a response aimed at addressing this crisis. Open Science practices here act as a civilizing force (Penders 2022) and address the irreplicability issue through technical solutions and transparency which enables monitoring of scientific practices. The

relation between Open Science and replication crisis will be discussed in detail in paper one of this thesis.

3.3. Openness, the public good vision and Commercialisation of science

Commercialisation has been identified as one of the main issues in science (e.g, Pinto 2020; Lave et al. 2010; Mirowski and Van Horn 2005), a state recognized as eroding public trust in science (de Melo-Martín and Intemann 2018), in which industrial and commercial interests affect or corrupt scientific knowledge production and dissemination (Pinto 2020). Empirically, the majority of the focus in the literature on commercialisation has centred on the pharmaceutical or tobacco industries (Mirowski and Van Horn 2005), but privatisation and commercialisation, characterised by the "integration of public science and private profit" have not been limited to these fields (Lave et al. 2010, 664).

Pinto (2020), from a philosophy of science perspective, describes the relation between public trust and commercialisation as complex. At one level, she highlights that commercial interests can directly influence scientific consensus in favour of certain results that are not epistemically reliable. For example, unfavourable scientific results for a drug may be suppressed by pharmaceutical companies. At another level, commercial interests can promote a narrow conception of trustworthiness to serve private interests, which occurs when industries or private entities focus only on epistemically reliable aspects while ignoring the broader context.

From a more structural perspective, De Melo-Martín and Intemann (2018), argue that commercialisation affects the epistemic aims of science and that research agendas can be skewed towards what is profitable rather than what is epistemically and socially valuable. Commercial involvement, in their view, brings conflicts of interests which may question the extent to which science serves the public good. They argue that these factors contribute to public distrust in science.

Another relevant term in this discussion is the *assetisation* of science, which focuses on the political economy of science. Birch (2017) illustrates assetisation through the vast number of scientific results protected by intellectual property rights, and argues that science, in its current condition, should be regarded as a business that sells something, rather than merely as part of R&D or the production process of goods and services.

Although some scholars argue that, similar to commercialisation, science has served political or religious obligations in the past, the claim is that the impact of commercialisation, in its

intensity and quality, on scientific production and freedom is different from that of other eras (Lave et al. 2010). In this view, under the rise of neoliberal scientific management after the1980s (Mirowski and Van Horn 2005) and aligned with a larger neoliberal political economic shift, the commercialisation of knowledge production and dissemination occurred through certain mechanism: namely the privatisation of universities, the decrease in public funding, the fortification of intellectual property, the dissolution of the author, and the separation of teaching and research responsibilities, which collectively have transformed knowledge in its practice and organisation (Lave et al. 2010, 659). These has turned universities into "competitive global services industries" (Lave et al. 2010, 665), heavily shaped by funding agencies and aligned with market imperatives, which endanger scientific autonomy (Lave et al. 2010).

Commercialisation brings back the question of whom science benefits, or which master it serves. Serving industrial and commercial goals is not necessarily aligned with the epistemic or social goals of science (Melo-Martín and Intemann 2009).

Some scholars view the aspects of science that are less transparent as responsible for the erosion of trust in science (Pinto 2020) and Open Science proponents, who argue for science to be free and accessible to all, address this issue. In the context of the open-source movement, it is also argued that Open Science visions run counter to commercialisation (Mackenzie et al. 2013). This contrast between commercialisation of science and Open Science discourse is not widely accepted. Scholars argue that Open Science and commercialisation are not necessarily irreconcilable, and that they can be considered part of a broader innovation framework (Caulfield et al. 2012) aligned with market imperatives (Mirowski 2018; Kansa 2014).

Practitioners of Open Science advocate for non-commercialised approaches and envision making data, research, and other forms of open knowledge to benefit society. These visions call for public funding to support these practices. The overall argument of Open Science advocates is based on three assumptions. Firstly, that making knowledge open benefits researchers and leads to scientific progress (Pampel and Dallmeier-Tiessen 2014). Secondly, that Open Science, through scientific progress or its existence, benefits society. And thirdly, that since Open Science contributes to the public benefit, the public should invest in it (Mirowski 2018). The first assumption is widely held among Open Science practitioners and advocates. For example, Tsipouri and others (2025) have shown in a review spanning 2003-2023 that Open Science has fostered innovation through free access and accelerated the

research process. However, the second and third assumptions have received comparatively less discussion or scrutiny in the literature.

Scholars have illustrated that, given the vast influence of private actors in science, the patenting of scientific findings, and commercialisation, scientific progress does not necessarily address the well-being of society (Toleubayev et al. 2010; Stengel et al. 2009; Vermeir 2013; Maskus and Reichman 2004; Mirowski and Sent 2002; Fuller 2020a).

Hence, amid the commercialisation of science, Kansa (2014) frames Open Science not as a reform, but as an entrenchment of neoliberalism within science. In his view, as neoliberal universities primarily serve the needs of commerce, it is unsurprising that opening science mostly benefits corporate R&D, which monetise science and technologies.

The vision of Open Science as benefitting the public through scientific practices, coupled with the argument for its public funding, resembles the "science as a public good" discussion in economics and science studies, which itself emerged as a response to the commercialisation of science.

The idea posits that science is a public good based on the principles of non-rivalry and non-excludability. As a public good, private entities would lack sufficient motivation to fund it, and therefore it should be publicly supported. This concept was initially developed through welfare state economics and later adapted within neoliberal ideologies (Fuller 2020a).

Callon (1994) introduced the discussion of "science as a public good" to STS from economics. He argued that science does not meet the two requirements of non-rivalry (meaning that one person's use does not reduce its availability to others) and non-excludability (meaning that use cannot prevent others from using it), and therefore does not qualify as a public good in the strict economic sense to justify its public investment. However, he advocates viewing science as a collective good, because it is a source of diversity and flexibility.

From a different line of reasoning, Fuller (2020a, 2020b) reaches a similar conclusion to Callon. Fuller (2020a), while rejecting the idea that science is a public good, argues that science is essentially a club good, since it is only open to certain groups of people and it does not benefit the broader public. Through a historical account, Fuller illustrates that, during 20th century, universities in England and US followed military agenda, pointing to different interests which drive scientific practices. He concludes that science has pursued and served the interests

of specific groups rather than society as a whole, rendering the argument for public funding of science rather tenuous.

Hence, in the era of commercialisation of science, it seems that Open Science proponents, who advocate for opening science and publicly funding it to benefit society, are making a leap from the claim that Open Science leads to scientific progress to the assumption that it benefits society.

Open Science is particularly attractive and useful for certain stakeholders, such as scientists, ICT professionals, and corporations. Yet, a trend of strong dependency on funding from public institutions can be observed in some Open Science practices, such as Citizen Science and Open Data. Mirowski (2018) criticises how Open Science practices may ultimately benefit private entities through public funding, or, in the case of Citizen Science, how the unpaid labour of citizen scientists may reduce costs for institutions. Generally, public actors approach Open Science from a normative standpoint, advocating for citizens' rights to access information and for public engagement. In many countries, such as the UK and the United States, they have supported the shift to Open Access by providing legal frameworks for it (Sitek and Bertelmann 2014). In addition, ICT professionals have become integral to nearly all facets of Open Science networks, facilitating the sharing of knowledge and information as well as transparency.

3.4. Summary of literature review

Interpreting Open science in a continuous temporality implies its normative aspect. Metaphorically, a normative interpretation of Open science as continuous across centuries, threads the past, present, and future of Open science into a linear existence. In that sense, Open Science should be preserved in the present and expected in the future as it is seen to originate from the early foundations of science. The normative aspect homogenizes ruptures and differences and implies that the normatively "best" practices have been continuously exercised.

On the other hand, seeing Open Science as distinct from past practices in science, foregrounds issues and crises in the current state of science and emphasises the promises for change. If Open Science is understood as a mode of scientific governance, its future-oriented aspect implies a problematic state within science. Being future-oriented, as Dobroć and Löcsch (2023) suggest, stems from the necessity of discarding the old in favour of the new. Similarly, Hausstein (2020) proposes that visions function as future-oriented responses to transformational imperatives caused by grand challenges (Hausstein 2020, 85). These authors,

conceptualize being future-oriented as a state that necessitates overcoming challenges, and rupturing from past approaches.

Weighing these two lines of reasoning, and especially regarding digital sharing technologies as the material enablers of current Open Science practices, the future-oriented aspect of Open Science signifies its connections to challenges and crises in science, a desire to move beyond the current state, and an aspiration to transform science through Open Science visions.

Open Science visions of transparency, participation, and public benefit are normatively well-accepted and are not widely questioned in terms of their legitimacy by Open Science practitioners. This reflects Borup's and others' (2006) argument that widely shared expectations do not require justification, as they can effectively compel stakeholders to adopt tools and follow procedures (Borup et al. 2006). For example, Open Science initiatives within scientific communities have created scientific routines and procedures, such as Open Science badges, pre-registration and pre-prints guidelines, open peer review, and Open Data, which scientists comply with (discussed in paper one). These initiatives have also shaped regulations for Open Access publishing and influenced the agendas of universities and policymakers to facilitate Open Access. From a broader perspective, this can be seen as an instance of notions and ideas becoming embedded within a discursive order.

Overall, this PhD thesis follows scholars who believe Open science has been enabled by and become widespread through digital technologies (Vicente-Saez and Martinez-Fuentes 2018). Digital sharing technologies should be regarded as tools which render specific enactments of Open Science visions because they come with their sociomaterial affordances and socialities. This makes the investigation of how visions are enacted in practice a relevant task for identifying changes in science. In what follows, certain aspects of Open Science visions are identified as the gaps in the literature which will later be probed in the four papers of this thesis.

3.4.1. Ambivalences in democratic vision:

There are notable ambivalences regarding the first vision of democratic participation in the relevant literature. Participation in science appears to play a dual role: some studies frame it as a remedy for public distrust in science, whereas others portray it as a contributor to the post-truth era.

For the time being, it is reasonable to assert that democratic participation in science, rather than being justified in practice, functions as part of a broader discursive order which values

representation in both political order and science (Soneryd and Sundqvist 2023). This perspective resonates with Sismondo's argument, which identifies political economies of knowledge as an underlying factor and interprets these practices as a symptomatic element within these political economies (Sismondo 2017).

The Open Science vision of participation comes through Citizen Science initiatives and Open governmental data. Determining whether democratic epistemology or participation exacerbates the post-truth condition or represents an attempt to restore public trust in science, requires empirical knowledge of the nuances of the initiatives, namely whether they are offering new social epistemologies or they are operating within predefined participation projects (Mahr and Dickel 2019; Ottinger 2022). In other words, each case is likely to exhibit particular characteristics depending on its context, and thus the enactment of this vision varies.

More importantly, the vision is materialised through policies, projects, and initiatives that reconfigure and shape knowledge infrastructures. This is because the post-truth era is strongly related to institutions and knowledge infrastructures as sources of credible knowledge production and, in that sense, single research projects and practices are not necessarily influential. For instance, in case of citizen science, it is crucial to investigate how the creation of parallel networks of participation affects the existing institutions and infrastructures. Similarly, in the case of open-source software and open governmental data, the extent to which the knowledge is democratised requires more investigation.

Hence, the empirical investigations of Open Science practices can reveal important insights into how the practices reconfigure scientific practices and interact with scientific knowledge infrastructures. Moreover, they can shed light on how democratic visions are enacted and explain why they fail or succeed.

3.4.2. Replicability

Regarding the replication crisis, Open Science practices as solution and the vision of transparency appear to be part of a discursive order for change in science (Penders 2022). STS scholars problematise both the usefulness of exact replication and the possibility of achieving replication through documenting research flow, as advocated in Open Science.

In 1975, Collins and Harrison, during their laboratory study, showed that even an expert builder of a TEA laser failed to replicate the experiment solely based on documented procedures. In their view, this failure was not due to a lack of specifications or sufficient data; rather, they

highlighted the importance of tacit knowledge and skills required for successful replication. Consequently, they argued that written instructions alone are insufficient for replicating an experiment (H. M. Collins and Harrison 1975). Later in 1992, Collins (1992) formalised this idea and developed the notion of experimenters' regress, presenting it both as a critique of replication in experimental science and as a theoretical argument for the social production of scientific knowledge. He contended that conducting an experience requires tacit knowledge of apparatuses and procedures, and one cannot ascertain whether an experiment has been executed correctly without seeing whether it produces the expected results. He further argued that replication is fundamentally dependent on experts' judgment and tacit knowledge. More recently, Feest (2019) by emphasising other types of replication such as conceptual replication instead of close/direct replication, argues that the failure of replication can be caused by lack of conceptual experimental design clarity.

In another example, Guttinger and Love (2019) argue that replication crisis is misunderstood because of its narrow methodological focus and its ignoring of the nature of the scientific process, which involves failures in replications. Alternatively, they suggest that science needs longitudinal research which combines different methods and explores the full range of conditions under which a phenomenon occurs (Guttinger and Love 2019).

These critical stances on replication makes Open Science practices more interesting to observe because Open Science digital solutions such as pre-registration and Open Data are addressing this crisis. A perceived central crisis in behavioural science has turned Open Science into part of a change in science towards a bureaucratised, digital, and transparent form of science.

The science studies literature, I argue, would benefit from a clear account of how Open Science is expected by behavioural scientists to realize replication in practice and how it is reconfiguring scientific practices and infrastructures.

3.4.3. Benefitting public

The assumption of scientific progress benefitting society overlooks the commercialisation and the involvement of private actors in science. As evident from a brief review of the literature, even though Open Science advocates argue that transparency and openness can foster scientific progress and innovations, they neglect the processes and infrastructures through which scientific advances translate into societal benefits. For example, they assume that society automatically gains benefit from economic growth (Tsipouri et al. 2025).

Moreover, this perspective overlooks the requirements for the duplication and transfer of knowledge. The term "open" in Open Science connotates with notions of accessibility and usability for all, but in practice, this is rarely the case. As Callon (1994) argues, for a piece of knowledge to be duplicated and used, a series of investments in reproduction, complementary assets, maintenance, and mobilisation is required. While investments in Open Science, address reproduction and maintenance, they fail to account for complementary assets (namely, the tools, skills, and other kinds of knowledge required to make sense of knowledge) and mobilization (namely, the use of knowledge in practice). Consequently, it cannot be assumed that the public or lay-people automatically benefit from opening science and data. On the contrary, only actors who have already received prior investments —whether from institutions, corporations, or in rare cases, their individual efforts— are able to make sense of and use Open Science and Data. Simply put, those with access to the requisite tools, skills, and networks derive the greatest benefit from Opening science[6], while commercialisation has already concentrated the most skills, opportunities, and resources in the hands of private entities.

Therefore, the funding and efforts allocated to Open Science, and provided by public purse, might not necessarily address the general public's interests, rather, they may serve the interests of certain groups. Greater attention in the literature is needed on the classic question of *cui bono*. This means that more research is required on the beneficiaries of Open Science and on those who are excluded from it within this specific vision.

This connects to a knowledge production perspective which states that openness does not persist in all stages of Open Science practices. Proprietary software or payment gates are also part of these Open science practices. Whether in the case of Open Access journals where the authors are required to pay a fee to publish their articles as Open Access, or in the case of open-source software, where such software may have crucial university and corporate ties (McInerney 2009), or in the case of Citizen Science, where initiators are required to pay for cloud or laboratory services, openness is constrained. This results in the exclusion of some groups or individuals from using, producing, and contributing to Open Science. The case of open-source code in online repositories exemplifies this point particularly well: although contributions to code development from skilled and interested parties, as well as distribution of the code in repositories in an open manner, are possible, the consumption or use of the code in a free manner is not guaranteed. A recent study has demonstrated that 97 percent of

[6] Here citizen science is an exception since it involves various cases of grassroot initiatives.

proprietary software and applications use open-source codes in a significant way ("Open Source Security and Risk Analysis Report Trends | Black Duck," n.d.). This implies that the main beneficiaries of open-source tools are private entities (Kansa 2014).

The concerns regarding the commercialisation of science and how Open Science may benefit private actors are crucial and valid. However, the commercialisation of science and criticisms that Open Science benefits corporate actors should not lead to a withdrawal from the very ideas behind Open Science. Empirical investigations are needed to examine what it means to have a *public good Open Science* and which infrastructures and sociomaterial relations are needed for Open Science to be transferred and used for the benefit of publics.

Now that the three visions are briefly discussed, it is also crucial to probe empirical cases in light of broader science-society relations. Connecting the origin of Open Science to past scientific governance, practices, or norms provides practitioners with a normative justification for the practices. However, the continuity approach is not strongly supported. Science seems to have been transparent in a specific way and presented only to selected groups of publics. In the case of the discussion by Shapin and Schaffer (1991), for example, even in Boyle's approach, two contradictory elements of egalitarian norms of transparency on one hand, and merit-based restrictions on membership on the other, were already present ((Yang 2020, 437) quoting Mark Brown) which points to the historical and contextual configurations of transparency.

Seven years after Shapin and Schaffer, Haraway (1997) in her book, *Modest_Witness@Second_Millennium,* made similar arguments and illustrated that science, during the time of Boyle and Hobbes in the 17th century, was not accessible to the public. Instead, the credibility of experiments could only be attested by a limited few who had the opportunity to witness them. Both these arguments imply that the openness of science was relative, even in the experimental, egalitarian way that Shapin and Schaffer described.

Shapin's and Schaffer's work has wider implications for this PhD thesis. They point to how methods and supposedly neutral techniques were entangled with the social and political concerns of 17th- century England and show how facts are produced through communal experimental witnessing by elites, trust in instruments (such as the air-pump), and shared conventions and rituals. More importantly, they illustrate how the "polity" constructed in scientific communities shapes the broader political realm and is shaped by it. In other words, Boyle's vision was aligned with that of democratic representative government.

These historical accounts reveal that scientific practices are situated and aligned within their social contexts and that even ideas of transparency and publics are shaped through the instruments and tools and, generally, the sociomaterial configurations of which scientific practices are part.

Another aspect worth noting is that these configurations, materially persist through standards, the built environment, habits, and classifications, which means that even though the idea of continuity in Open Science practices is not well-supported due to the importance of digital technologies in their current configurations, infrastructures carry past temporalities.

In the case of Open Science and the pursuit of its visions, two points can be built on the literature, firstly, the contextualisation of Open Science in a wider political order; and secondly, the enactment of each vision as a driver of change that interacts with existing infrastructures.

3.5. Visions vs. materialities, addressing the gap in the literature

The relationship between visions and materialities has been extensively discussed in the STS literature (Landström and Soneryd 2024; Tutton 2017; Borup et al. 2006). One of the main arguments highlights the performativity of visions and how visions and materialities are mutually shaped and enacted (Borup et al. 2006). Importantly, this argument challenges the distinction between what is real and what is imagined (Tutton 2017, 480). Based on this argument, visions and expectations are constrained by and emerge from materialities, meaning that they are continually recalibrated and modified when encountering resistance from materialities (Tutton 2017).

On the other hand, visions and expectations can enable or facilitate actions and shape materialities. Ultimately, expectations can create path-dependencies and lock-ins (Tutton 2017; Landström and Soneryd 2024). This means that envisioning a certain kind of future can constrain future possibilities by privileging some futures while marginalising others through the allocation of resources and the guidance of actions. This notion resonates with what Nost (2022) examines in his article. He demonstrates how experts attempt to build data infrastructures, work with existing data and tools, and invest resources to gather more data, which results in a focus on data-driven governance, whereby existing goals and frameworks are extended into the future. This process limits the future possibilities of how problems are

defined, what kinds of expertise are needed for those problems, and what types of data and resources are required.

While this PhD thesis follows the assumption that visions and materialities are co-constructed, it also emphasises the non-linear relationship between the two (Landström and Soneryd 2024) and foregrounds the notion that visions might be part of a discursive order or evolve into hegemonic ideologies that travel from one context to other irrelevant ones, thereby becoming misplaced or failing to build sustained networks.

As discussed, Open Science is promoted through positive visions and is regarded as a panacea by policy and funding bodies, as well as by Open Science advocates, for solving existing issues and crises in science, a view that has been critiqued by scholars (Mirowski 2018; Leonelli 2023). Within different practices and scales, visions of Open Science vary. However, they highlight transparency, democratic participation, and public benefit. Through these visions, Open Science is expected to restore public trust in science, solve its replicability crisis, and accelerate scientific and technological progress to benefit society (Vicente-Saez and Martinez-Fuentes 2018; Leonelli 2023).

Most importantly, for enacting these visions through Open Science practices, certain technologies and infrastructures are needed that enable the flow and maintenance of data. In other words, through visions of Open Science, each practice is attached to Information and Communication Technology (ICT) actors. These actors serve as both providers and maintainers of information infrastructures, and through them, new socialities are formed (Bowker et al. 2009). In that sense, even before turning to empirical materials, we know that the visions, if pursued through Open Science practices, are inviting digital configurations and marginalising non-digital futures. However, if the visions truly address the central crises in science, it is crucially important to understand how they reconfigure knowledge and specifically scientific infrastructures.

Following this, one area which can be discussed more in the science studies literature is the relation between Open Science as a new governance of science, and visions aimed at overcoming crises and existing scientific infrastructures. Open Science, in its infrastructuring practices has already created new networks and socialities with new kinds of expertise previously not involved in science. Computer science and data repositories have been infrastructured into natural science fields. Open Science has also created standards, routines, and mandates on how to share and open research and data, and how to delegate research tasks

to machines and humans in new ways. These aspects, in some cases in the form of visions and principles (intellectual and immaterial) and in other cases through the processes of infrastructuring, affect existing infrastructures. Open Science practices can destabilise and weaken established infrastructures, or they themselves can become part of existing infrastructures and reconfigure them. How these visions and materialities shape each existing infrastructure requires empirical investigation within each context.

It is crucial to note, though, that the processes of infrastructuring are not merely digitalisation processes, which happen in other fields as well. Rather, particular visions of Open science, aiming to blur scientist-non-scientist expertise, point to the very core of scientific infrastructures as the infrastructures that produce credible knowledge. Open Science practices, claiming to produce knowledge outside science's borders address the legitimacy of science. Moreover, the notions of transparency and sharing presuppose that science is exposed to and witnessed by actors outside science.

This is not to claim that Open Science single-handedly contributes to the reconfiguration of scientific infrastructures; rather, Open Science is a symptom of reordering, not only in scientific infrastructures but also in broader discursive politics in society. Indeed, re-infrastructuring and reconfiguring science through a new governance of science, following Shapin and Schaffer (1991), has wider implications. Democratisation, participation, replicability, and the idea that transparency benefits society all reveal a wider social order where the envisioned norms interact with existing infrastructures.

Hence, some of the visions of Open Science have already been enacted and turned into infrastructures where standards and regulations are established or networks are formed, along with them certain futures enacted and some marginalised (Brown and Rappert 2017). As Brown and Rappert (2017, 6) mention, futures as a contested terrain, "are stabilised around specific sets of expectations and practices". This raises important questions about why certain visions and expectations of Open Science practices fail, how they unfold over time.

To address existing gaps in the literature, this PhD thesis investigates the overarching visions of Open Science and their enactments in empirical cases. Concerning the vision of replication and transparency, it seeks to fill the gap regarding how Open Science is turning from a set of normative visions into infrastructures. The central research question of this vision is: "How is Open Science expected to reconfigure scientific practice within a specific scientific field?"

With respect to the vision of democratic participation, this PhD thesis engages with two distinct gaps. First, it addresses the lack of research on how parallel structures of knowledge production operate and the challenges they encounter. The corresponding research question is: “What are the limitations of participatory knowledge making situated outside science, and why do such initiatives not endure?” Second, it tackles the underexplored issue of the failure of participation vision through open governmental data. This aspect is guided by the questions: “Why does Open Data fail to deliver on its democratic participation vision, and how are visions of democratic participation enacted from a policymaker’s point of view?”

It is important to clarify the meaning of the term *democratic* while investigating democratic participation in my case study. By democratic, I refer to political and material configurations that are constituted through representation. This foregrounds the idea of scale, which implies that while democratic configurations exist at the city level in some contexts, they might be functioning differently at the national level. Moreover, the vision of democratic participation can emerge in diverse contexts. The vision, in its enactment, can either bring change to the context or fail.

Finally, in examining the vision of public benefit and the public good, the PhD thesis responds to the gap concerning what a public good Open Science might entail. Through an empirical case, it revisits the question of *cui bono* while asking, “Under what sociomaterial relations and processes does Open Science benefit the publics?”

4. Remarks about method

4.1. Infrastructure as methodology

Bowker and Star (1999) point to the invisibility of functioning infrastructures and that infrastructure are never transparent to everyone (Bowker and Star 1999, 33), but rather only to certain communities and users. They mention that the invisibility of infrastructures works as a barrier for outsider to study them. Through some methodological attentions, they suggest that a deeper understanding of "how people meet infrastructures" (Bowker and Star 1999, 33) can be acquired.

During the course of my research on Open Science, I conceptualised Open Science visions in relation to certain issues and crisis in the science-society relationship, which meant that all my cases are selected in relation to issues, crises, and failures in science and policy. Developing an infrastructural lens for studying these issues, failures, and crises helped me to trace infrastructuring efforts as well as infrastructural breakdowns and vulnerabilities. In other words, I studied almost-infrastructures, not-working-smoothly, frequently breaking-down, old, or vulnerable ones.

Star (1999) claims that studying information systems implicitly involves the study of infrastructures. However, I don't follow this assumption; rather, I argue that adopting an infrastructure lens requires the researcher to demarcate infrastructures and identify whether standards and classifications in the information systems have been turned into infrastructures.

In this PhD thesis, I follow Edwards (2003) in regarding infrastructure from a variety of scales and social organisations. In my view, the methodological implications for developing an infrastructural lens in this PhD thesis occur on three overlapping levels of visions, practices of infrastructuring, and their relation to existing infrastructures.

The first level is to understand visions of infrastructuring or infrastructural changes. To study visions echoes Star's (1999) articulation of studying master narratives in an infrastructure: in questioning and probing them, in their unifications, personifications, and monolithic agendas. However, visions, as previously mentioned, function on a different temporality than narratives and are inherently future-oriented.

The second level focuses on the actual infrastructuring practices such as making standards, routines, and regulations (Star 1999; Bowker and Star 1999). This level is traced in relation to visions through texts, interviews, and observations. It is at this level that I aimed to surface the

invisible work (Star 1999) of Open Science practices and understand the activities that go unnoticed.

At the third level, an infrastructure lens contributes to understanding how visions and practices reshape existing infrastructures. This is close to what Edwards (2003) mentions as the meso-level scale where the focus is more on the functionality of infrastructures and infrastructural changes rather than on practices and standards.

4.2. Details on methods

The diversity of Open Science visions in each practices led this PhD thesis to adopt a pluralist approach in using STS methods. The aim was to study Open Science visions related to the replicability of research, democratic participation, and public benefit.

Moreover, each vision required choosing a practice where the vision was most prominent. Asdal and Marres (2014), in their material-semiotic approach, highlight the importance of tracing and discussing issues and objects simultaneously. This PhD thesis also sees visions and materialities as indivisible, especially in future-oriented practices of Open Science.

The most prominent methodological challenge of this thesis was to create a coherent account of studying the enactment of visions of Open Science. To address this challenge, for each vision I focused on the vision holders or the actors who were actively pushing the agenda of Open Science practices. As Asdal notes: “In every story, it matters who, or what, gets to play the main characters” (Asdal 2015, 60). However, this does not mean that I follow a human-centred approach to agency, rather I believe one way of accessing collective crystallised visions of Open science practices is to study the initiators’, policymakers’, scientists’ and developers’ collective narratives in case studies. Therefore, in all four practices I searched for how these vision holders or as Leonelli (2023) articulates them, Open Science activists, frame the visions.

This matter explains the diversity of methods in this PhD thesis, including mixed methods (systematic literature review and thematic analysis), participant observation, interview study, ethnographic visits and document analysis, as each vision of replicability in science, democratic participation, and public benefit required and dictated a specific method to capture visions and their enactments (Table 1).

In the next section I will briefly review the main methods of each of the paper.

Research	Interview	Ethnographic visit	Participant Observation	Systematic literature review, Scientometrics	Qualitative text analysis	Document analysis
Paper one: Visions of replicability through academic published paper				✓	✓	
Paper two: Vision of democratic participation through citizen observatory initiators (core members)	✓					✓
Paper three: vision of democratic participation through policymakers			✓			✓
Paper four: vision of benefitting public through Open-source developers	✓	✓				✓

Table 1 Method and data sources overview

4.2.1. Systematic Literature Review and qualitative analysis of the text

One area in which Open Science activists advocate for and promote the practices and ideas of Open Science is through published academic papers. To study the vast amount of information published on Open Science and in order to understand its visions and expectations, how and why the practices are prescribed or advocated, there is a need for two tasks: first, to get an overview of the texts and how they are connected through systematic literature review (SLR) and scientometrics, and second, to conduct a qualitative analysis of the identified clusters of articles.

Scholars have mentioned that qualitative and quantitative studies of science have diverged over time (Wyatt et al. 2015). However, recently, there has been an emerging mixed-methods trend

in STS due to the vast amount of digitally stored information (Moats and Borra 2018; Latour et al. 2012). STS researchers have developed innovative ways of employing mixed methods to explore digital information in an interpretative and reflective way (Venturini et al. 2014; Venturini et al. 2017; Blok and Pedersen 2014; Cambrosio, Cointet, and Abdo 2020; Moats and Borra 2018; Bornakke and Due 2018).

For studying Open Science visions in a large body of published articles, we first utilised the SLR technique along with scientometrics to identify the main networks of discussions among scholars. We considered the networks drawn as a result of scientometric techniques as algorithmic constructs (Wyatt et al. 2015), not as facts, which outlined the discussion of the replication crisis in behavioural science and the Open Science solution to it. The quantitative approach was then followed by a qualitative analysis of the texts in the identified networks to answer the research questions.

4.2.2. Interviews and document analysis

In comparing citizen observatory initiatives, their visions, how they are organised and how they last, I used interviews as the main method. The interviews, as Trauffmansdoff and Felt suggest, are crucial for narrative production (2023, 641). The interviews are aimed at identifying the main expectations, visions, activities, and how the initiatives are sustained.

The interviews were complemented by an analysis of the documents, online materials, and reports produced by each of the initiatives to provide a better understanding of the collective visions and their enactments. Following STS scholars, documents are regarded alongside the initiators' visions and as part of the reality (Asdal 2015) with a transforming capacity (Sepehr and Felt 2025) through the material-semiotic approach. However, the data from document analysis, mostly informed my assessment of the interviews and was not used explicitly.

4.2.3. Retrospective participant observation and document analysis

The main method in studying policymakers' visions of democratic participation using Open Science practices was retrospective participant observation (Bernard 2017), approaching the subject from the perspective of the policymakers in the Smart City and Transparency Committee of the Tehran city Council (the Committee).

My dual positions, both as a former employee of the Committee and as a PhD student reconstructing her memory through documents and notes, had two aspects: first, I was faced with the challenge of applying ethical considerations to the professional experience I had; and

second, it gave me unique, situated knowledge from policy makers' point of view (Haraway 1988). It is also crucial to be aware that my experience as a former employee is a subset of that specific situation and is shaped by uneven power relations and the author's location in the stakeholders matrix (Simandan 2019, 130).

Hence, this research was initiated by a retrospective auto-ethnographic approach (Bell et al. 2020; Ellis et al. 2011) as a reflection to revisit and make sense of a collective experience in which I participated. To do so, I reconstructed memories of concrete practices and efforts, filled memory gaps with documents, and scrutinized both recurring themes and phased-out agendas.

The main data sources for this research are notes as a facilitator and researcher, official meetings materials, and the published Open Data.

4.2.4. Ethnographic visits, interviews and document analysis

Studying Open Science practices, similar to studying other information systems, knowledge infrastructures, online offline communities, and e-science initiatives (Star 1999; Beaulieu 2010), differs from traditional ways of conducting ethnographic research in STS. In other words, it might be unnecessary or not feasible to provide a comprehensive ethnographic account of Open Science case studies. In my PhD thesis, I follow Beaulieu in advocating for the decentralization of the notion of space in ethnographic works. She proposes the idea of "loosing the grip on being in the field" (Beaulieu 2010). Following this approach, I complemented ethnographic visits with interviews visit instead of being in the workplace of the experts and scientists for a long period. For example, for studying the use of Open Source in water infrastructure, while having an ethnographic approach I drew on materials such as policy documents and budget files along with conducting the interviews and attending few ethnographic visits.

4.3. Ethics

The concept of situated knowledge can help clarify the ethics of each study in this PhD thesis. Lippert and Mewes (2021, 3), drawing on Haraway, interpret ethics as attempts to make "knowledge practices explicit through accountability and response-ability". I draw on this notion to clarify the research processes of my thesis, to position myself in each case responsibly and search for ways to improve the studied practices. Moreover, I have attempted to represent advocates of Open Science fairly, especially when their solutions seemed problematic or

technocratic to me. I have also been mindful of the possible consequences of my studies on groups' reputation or on the marginalisation of specific practices.

During my research on Open science, I followed good research practices in general terms (Swedish Research Council (Vetenskapsrådet) 2024). This meant that I ensured transparency by writing the details of my methods and results. In the case of the retrospective study in Tehran (paper three) I disclosed the conflict of interest arguing that my prior role of being part of the policymaking team has shaped the research on how I portray the attempts to open data and improve the digital tools, as well as the assessment of failure and success of the tools, thereby leading to potential bias.

Moreover, I planned, conducted, and analysed my research responsibly, ensuring that no harm was done to any groups, or individuals represented in the study and that all work was carried out in accordance with ethical principles and regulations. This means that I was careful not to undermine their attempts to contribute to democratic participation, transparency, and public benefit and avoided representing individuals and groups in a negative way. Instead, I focused on trends, sociomaterial relations, and processes.

Additionally, the ethical principles of protecting identities and confidentiality, considering representation of others, and exploring possible consequences of research were followed in all cases (Tullis 2021). In general, I refrained from specifying names and organisations whenever possible. However, due to my different roles, positionalities, and methods this principle could not be applied uniformly everywhere. In the case of the retrospective study in Tehran, my method did not allow for the anonymisation of name of the city or for following the same sets of ethical procedures as in the case of the use of open-source tool in the water infrastructure of an Scandinavian city (paper four), although both were within public sector organisations. However, I avoided discussing any work environment descriptions or focusing on individual efforts and activities. I also reflected on ethical considerations and my positionality in each case during the planning, methodological design, analysis, and writing phases of the research.

The first study in my thesis was conducted through a systematic literature review and text analysis, which did not require the collection of any non-publicly available information. The remaining three studies, however, involved interviews and observations.

Before interviewing the experts and individuals, informed consent was obtained in my second and fourth studies, and I shared my participant information sheet clarifying my obligations during the interviews and after, both via email and orally at the beginning of each interview

(Table 1). While conducting and analysing the interviews, I maintained proper documentation and data management, and discarded recordings after transcription. In the case of Tehran, however, the main challenge was my dual role as a former employee and researcher, which prevented me from obtaining ethical permission from the team during data collection (J. Edwards 2021). To address this, the focus was placed on my own experience, rather than on other employees in the municipal bureaus, private ICT companies or the general work environment.

Last but not least, I avoided fabrication, plagiarism or other deviations or fraud in my research.

• The insight from our meeting will be used solely in my ongoing PhD project on Open Science at Chalmers University of Technology. • My notes from this meeting can be shared with you upon request. • I will not mention any names or any characteristics of the people before getting permission from you. • I will not collect any sensitive information. • All meeting data will be confidential. My notes will be kept securely and will neither be shared with other parties nor used for other purposes. • These insights will be used in my PhD project, which may later be part contribute to a published paper. • Lastly, the participation in this meeting is voluntarily and can be stopped at any step.

Table 2 Example of participant information sheet sent before interviews for paper two and paper four

5. Cases addressing research questions

Here, the four studies conducted to answer the research questions are briefly reviewed.

5.1. Open Science as an infrastructure solution to the replication crisis

Open Science has been defined as part of a scientific reform (Penders 2022). However, we have limited knowledge of what this scientific reform means in different fields and how it shapes them. This study addresses the gap in the Open Science literature concerning how Open Science is envisioned by scholars to reshape and transform a specific scientific field. It frames Open Science in close connection to the emergence of new infrastructures for data sharing that enable transparency and Open Access (Ramjoué 2015). Focusing on the period from 2006-2021, we ask how OS was envisioned in writings by scientists at a time when it began to be implemented. To address this question, we use systematic review techniques to identify a cluster of articles discussing OS in scientific journals and conduct a qualitative analysis of the text.

The study revisits the STS interest in studying published scientific texts and treats published scientific texts as sites where scientists advocate for their practices, epistemology, and methods. The importance of employing such an approach is emphasised by the quantification of research, the multiplication of scientific articles, and the reframing of scientific research as a series of few-year projects. The focus on scientific publications addresses scientists as stakeholders who practice, discuss, or advocate for Open Science practices.

The research deployed a mixed-method approach to identify a cluster of connected articles discussing Open Science. For the quantitative part, we drew on systematic literature review techniques, limiting our search to English-language academic journals published between 2017 and 2021 in the *Scopus* and *Web of Science* academic databases. Using co-word analysis and bibliographic coupling, we then identified a cluster of articles interconnected through citations and their central keyword, “Open Science”. This gave us a cluster consisting of 148 unique articles which together created a discussion among behavioural scientists on Open Science. The articles within the cluster were connected to each other through citations and their most frequent keywords of Open data, Open access, Big data, Data science, Data sharing, Citizen science, Data management, Collaboration, Open source, Research data, Innovation, Metadata, Preregistration, Meta-analysis, Replicability, Reproducibility, Transparency, Peer review, and Scholarly communication.

Then, we qualitatively analysed the articles in the cluster to answer how Open Science is articulated and understood among behavioural scientists as the main vision holders of the field and how it is envisioned to reconfigure scientific practices. The analysis revealed that Open Science practitioners, advocates, or as Leonelli (2023) frames them, Open Science activists, envision it as a means to address the replication crisis in their fields and to change scientific practices. Open Science activists reconstruct the replication and reproducibility crisis, approaching it from a statistical point of view which can be resolved through moral and academic control via transparency. To achieve this version of replication, which is similar to what is called as computational replication (Obels et al. 2020; Kitzes et al. 2018), Open Science practices provide free access to data and research workflows stored in digital repositories. This version provides a technocratic version of the replication issue which can be solved or prevented through Open Science practices. The articles in the studied cluster address the issue of irreplicability of scientific research, Open Science practices such as new standards, guidelines, and protocols need to be implemented. Overall, the efforts seem to regulate behavioural science in a new way which is characterised by digitally stored research processes, shared data, and quantitative research processes.

The Open Science solution to the reproducibility/replicability problem marginalises interpretative and qualitative research in fields such as social psychology, prioritising digitally shared, quantitative, and large-scale research practices. More importantly, it advances a new social organisation of behavioural science, as established disciplinary scientific expertise is regarded as insufficient to guarantee credibility and replicability in scientific procedure. Consequently, new resources must be allocated towards the development and maintenance of digital networks and infrastructures, thereby precipitating a change in the nature and conditions of knowledge production in behavioural sciences.

Overall, Open Science activists, critical of the current scientific culture and of human fallibility, envisage a digitally archived behavioural science, featuring detailed workflow reports, larger sample sizes, and repeated statistical analyses. This represents a technocratic view of Open Science as an infrastructure that establishes a new order within behavioural science. Whether this vision of Open Science is unique to behavioural science or manifests itself in other fields remains a question for future research.

By developing an infrastructure lens, this research offers two key insights. First, it conceptualises Open Science as an emerging infrastructure rather than merely a set of

philosophical and intellectual trends or practices, thereby enabling a more comprehensive understanding of both the material and social aspects of Open Science. Second, the research demonstrates how Open Science visions necessitate infrastructure, including repositories, standards, badges, protocols, and platforms, which collectively reshape scientific practices and the organisation of science in this specific field. Therefore, Open Science practices employed by scientists in the field, contribute to the emergence of a new kind of infrastructure, embedding norms of transparency and control within knowledge production.

5.2. Citizen Science without Scientific infrastructures: Temporal Vulnerabilities of Environmental Citizen Observatories

Citizen Science is associated with a new governance of science (M. A. Peters 2010, 105–6), which reconfigures legitimacy and expertise, thereby making science more democratic, collaborative, and participatory. Numerous Citizen Science projects have been initiated and funded by universities, public authorities, and groups of publics, promising to contribute to a more efficient research process, accelerate scientific progress, educate publics, democratise science (Strasser et al. 2019; Raddick et al. 2019), or bring about societal or policy changes (Gramaglia and Mélard 2019; Kinchy et al. 2014; Jennifer Gabrys 2017).

Citizen Science literature discusses the epistemic, methodological, and political potentials of building citizen science initiatives (e.g., Ottinger 2022; Mahr and Dickel 2019). Also, it has addressed issues of legitimacy in participatory initiatives by examining power asymmetries, trust, and ignorance (Landström et al. 2011; J. Gabrys 2016; Ottinger 2022; Kasperowski and Hagen 2022; Blacker et al. 2021). However, the role of science as an infrastructure has been mostly overlooked in relation to the durability of participatory initiatives. In other words, it remains underexplored how such initiatives sustain themselves when they are not directly tied to scientific infrastructure and hence do not benefit from scientific legitimacy and resources. This study addresses this gap by focusing on a very specific kind of Citizen Science, which is called Environmental Citizen Observatory.

I use the concept of *Citizen Observatory*, which has been popularized by the European Commission (2014) to refer to a multi-aim, community-based environmental monitoring tool and information systems for informing environmental policy making, engaging citizens in decision-making, and complementing monitoring networks (European Commission 2017b, 2017a). The initiatives are facilitated by regulations and directives such as the Aarhus

Convention, which enables informed citizen involvement in environmental policies, the Citizens' Equality, Rights, and Values Programme promoting citizen participation, and the Water Framework Directive and are funded by several EU projects. In this research, to limit the scope of the initiatives, the term environmental is added to the concept of Citizen Observatory.

I formulate a distinction between Environmental Citizen Observatories and Citizen science, arguing that the former emerged within the EU political context and exists outside scientific infrastructures, whereas Citizen Science either has active scientific collaborations, or operates as part of scientific knowledge infrastructures.

Our exploratory search reveals that despite initially aiming for long-term monitoring visions, many Environmental Citizen Observatories, struggle to sustain themselves after their first round of funding. Although traces of some initiatives can be found in published articles and on funding agencies' websites, most projects tend to end after only a few years and become inactive. This raises questions about the durability of Environmental Citizen Observatories and suggests that community-based participatory science might be transient and vulnerable.

For addressing how these initiatives can endure for enacting their long-term monitoring vision, without being anchored or incorporated into existing knowledge infrastructures, this study compares four cases of Environmental Citizen Observatories in western Europe. The cases were identified following an exploratory search on the use of digital tools for public participation (Landström and Mokhtabad Amrei 2022), and were selected to maximise diversity in terms of internal organisation, network building, and types of participation. The first three cases (Drinkable Rivers, Citizen Crane, and EyeOnWater) focused on monitoring pollution and water quality, while the last case, Flamenco aimed to create a platform for groups and individuals to build their own observatories. Except for *Flamenco*, the other three cases remained active at the time of the research in 2023.

A qualitative approach was employed, mainly focusing on semi-structured interviews with individuals involved in the development and operation of the four initiatives. The interviews were complemented by online documents and videos from the initiatives. Through the interviews, my aim was to understand the main vision for initiating each case, the challenges encountered, and how the cases were sustained. I examined how each case was connected with other stakeholders such as universities, decision-making bodies, and the publics. The four cases

revealed struggles in sustaining themselves which can be interpreted as tensions between the visions of long-term monitoring and their material vulnerabilities.

The relevant literature on Citizen Science emphasises that the initiatives which deliberately position themselves outside scientific infrastructures, can create alternative social epistemologies (Mahr and Dickel 2019; Ottinger 2022) while navigating the trade-offs between independence and scientific legitimacy. This means that those Citizen Science projects can blur the lay-expert division through adding experimental ways of producing and validating knowledge by creating new indicators, practices, data collection methods, and coming up with their own problem definitions. Within the compared cases, I observed the creation of alternative methodologies or data-collection practices, particularly in *Drinkable Rivers* and *Citizen Crane*. For example, in *Citizen Crane*, the *Riverfly Monitoring Initiative* was a method where volunteers counted and monitored aquatic insects as indicators of river health by regularly sampling riverfly populations. Interestingly, in *Drinkable Rivers*, the team came up with the drinkability of river water as an indicator of overall water quality and ecosystem health.

This study shows that, despite achieving methodological, policy, or technical impacts, the Environmental Citizen Observatories face a mismatch between their long-term monitoring ambitions and their vulnerable materialities. The cases reveal vulnerabilities linked to a lack of legitimacy and scientific credibility, which are necessary to secure funding for sustainability and recognition by environmental management and policymaking bodies.

Since they are heavily dependent on their core members for a wide range of activities from marketing materials and recruitment to preparing financial reports, etc., this study argues that, to secure their funding and sustain themselves, they need to get infrastructured. However, as observed in the cases, Environmental Citizen Observatories face difficulties in establishing networks to legitimise their data, methods, or standards in environmental management.

The absence of scientific infrastructures in their organisations prevents these initiatives from legitimising and validating their data, methods, and standards, as well as from securing sustained funding. Additionally, the project format of these initiatives requires them to continuously seek funding and build networks. However, to achieve these goals, they must first establish legitimacy.

The cases show that if Environmental Citizen Observatories do not get to a certain degree of infrastructuring for getting legitimacy, they will not be able to be part of environmental management and policymaking. This poses a risk to their durability. The four cases exhibit

varying degrees of infrastructuring. The highest is shown in the case of *Citizen Crane*, where the initiative was successful in having their data infrastructured in environmental management. This provided *Citizen Crane* with a relatively more secured place to continue their environmental monitoring vision. This finding confirms what Jalbert discusses about the idea that Citizen Observatories can compensate for the lack of legitimacy and credibility resulting through making networks and partnerships (Jalbert 2016). In the case of *Drinkable Rivers*, the networks were also created, but they were vulnerable as they relied on the active champion role. In the two other cases, the team had to come up with creative ideas to endure. While *EyeOnWater* survived by allocating funds from other projects, *Flamenco* was unable to create networks to sustain funding.

As a result, we conclude that the durability of Environmental Citizen Observatories which is needed to fulfil the vision of long-term monitoring, is threatened by the lack of infrastructure connecting them with science.

The infrastructural perspective has enhanced our analysis by distinguishing between networks and infrastructure, clarifying that in the absence of infrastructure, initiatives remain mostly short-lived, despite forming networks or mobilising participants.

By conducting this research, I add to the understanding of the nuances and challenges associated with visions of democratic participation in Open Science practices. Furthermore, this research contributes to infrastructure studies by conceptualizing legitimacy and durability in relation to infrastructure, highlighting how alternative strategies for gaining legitimacy overload individuals.

5.3. Failing to Facilitate the Flow of a Public Infrastructure: A Policymakers' Story to Improve Reporting Tools in Tehran

The third study foregrounds the concept of flow (Larkin 2013; P. N. Edwards 2003; Castells 2011) in infrastructures to emphasise the dissemination and circulation of knowledge, ideas and things, and to explain failures in participatory and transparency visions. It builds on the relevant discussions on the visions of public engagement and democratic participation through participatory digital tools and Open Data situated within the smart city discourse and addresses the gap in the literature regarding failed visions and practices which did not sustain. Moreover, while most literature produces knowledge claims from outside the domains of policymaking and urban governance (Große-Bley and Kostka 2021, 3; Felt and Fochler 2010;

Krzywoszynska et al. 2018), this research focuses on the policymakers' perspective, as the agents of change.

This research reconstructs policymakers' perspective on employing these tools and reflects retrospectively on the knowledge situated in policymakers' visions and practices. It does so by revisiting the case of Tehran, where the urban governance employed digital technologies to facilitate civic engagement under the rhetoric of the smart city, Open Data, and transparency, specifically aiming to improve two participatory tools and make their data publicly accessible.

To investigate policymakers' visions and their enactments, this study primarily employs retrospective participant observation (Bernard 2017), approaching the subject from the perspective of policymakers in the Smart City and Transparency Committee of the Tehran City Council (the Committee). The research is initiated through a retrospective autoethnographic (Bell et al. 2020; Ellis et al. 2011) reflection to revisit and make sense of a collective experience in which I participated. To do so, I reconstructed memories of concrete and documented practices and efforts, filled in memory gaps with documents, and scrutinised both recurring themes and phased-out agendas.

Upon joining the Committee in 2018 as a researcher and facilitator, I was assigned to "improve" the two municipal reporting tools of 137 and 1888. The tools were initially city-wide call centres through which citizens could report urban issues to the municipality, and the Inspection Bureau of the municipality would assign them a ticket number while processing their reports. Over time, the tools evolved to include websites and mobile applications. The reports, meeting notes related to the two tools, and Open Data derived from them were made public during the Committee's tenure.

Drawing on Haraway's (1988) notion of situated knowledge, this research emphasises that knowledge is partial, fragmented, and dynamic (Ottinger 2013), as well as locatable, embodied, and influenced by researchers' identities and positions, which in this study refers to policymakers' vision and acknowledges that information derived from the author's position as a former employee of the Committee constitutes a subset of the broader situation.

The findings show that the studied infrastructure of the two reporting tools, a large-scale, well-established, and popular call centre, operated with rigid classifications and a high rate of report exclusions from its information flow. Overall, obstructions in the information flow manifested in five ways: in the translation of issues into classified topics, in the mass rejection of citizen knowledge during standardisation of reports, in resistance to enabling feedback, in reluctance

to open data, and in the municipal departments' unwillingness to utilise decision-support data produced from the two tools.

With the emergence of the new smart city and transparency discourse, municipal bureaus and the Committee shifted the established infrastructure into an "infrastructuring" mode (Nost 2022) and attempted to address these obstructions in the flow of reports through a series of alignment works. The overall vision was to enhance participation and increase efficiency, pursued primarily through technical solutions. Although this aspiration to improve brought about important changes at the practice level, it failed to address the politics and embedded standards within the infrastructure, which received citizens' reports but resisted incorporating the necessary attachments to turn individual situated knowledge into codified expert knowledge. In addition, the Open Data published from these tools was not used by any institution, group, or individual.

The failure of the Open Data vision can be explained by a logic similar to Callon's argument on replicability, in which he emphasises that knowledge cannot be transferred if, along with the knowledge itself, its attachments, that is, the necessary skills and instruments, are not transferred (Callon 1994).

To illustrate reasons for failure in the visions of opening data and improving citizen engagement through alignment works, I argue that adding smart solutions into existing infrastructures was pursued with the aim of increasing flow within the infrastructure by policymakers and municipal actors. However, obstructions in the information flow between citizens and municipal decision-makers were associated to the politics of infrastructure and extended beyond practice-level alignments.

Citizen reports remained static outside the infrastructure in the form of Open Data, as they required tools and skills to make sense of them and make them flow. On the other hand, the flow of citizen knowledge within the infrastructure was not facilitated by smart solutions because it lacked the standards and criteria necessary to be infrastructured, which would assess the knowledge through established valuation practices.

Through this case study, I illustrate that the flow of information in an infrastructure does not occur naturally through processes of digitalisation or smartification. Rather, information tends to remain static, and flow is shaped by the existing valuation practices within the infrastructure.

5.4. Reviving Public Good through Infrastructure: The Case of Open-source Tools in a Water Infrastructure

The fourth study centres around the vision of benefitting the public and focuses on the use of open-source tools in the water and waste management infrastructure of a Scandinavian city. The research asks how open science benefits the public and how it can be manifested as a public good. It showcases the transfer, dissemination, and use of open-source knowledge. This empirical study addresses the gap in the literature regarding how open-source can benefit the public and what a public-good-oriented open-source might entail.

In the studied case, Open-source tools were employed to address water leakage in the distribution network of the water infrastructure. On average, 15 percent of water in the network is leaked out of the network, causing costs for the city and damage to urban infrastructures. Instead of purchasing proprietary software or outsourcing the task, the team in the water company, which is responsible for the management of the water infrastructure, chose to use Open-Source tools and develop the requirements in-house.

The research answers its question through an ethnographic approach (Bernard 2017). It employs expert interviews as its main method accompanied by ethnographic visits (Beaulieu 2010) and policy document analysis (Asdal 2015). During the interviews, the focus was on the following themes: 1) visions of using open-source tools, 2) the activities required and undertaken in order to deploy open-source tools, 3) sociomaterial relations between the residents and the water infrastructure, and 4) the wider organisational changes.

The findings highlight the requirements for utilising open-source tools in an infrastructure. The requirements include more involvement of data science expertise as part of organisational change to identify, tweak, and develop the shared code and packages existing in online repositories. It also includes establishing a working platform which connects different data sources with data users such as city residents, construction teams in the street, and the management. The findings emphasise that the task of replicating a package of knowledge, although claimed to be free and open, is not equivalent to simply sharing it in digital repositories. Rather, it involves certain requirements regarding expertise, practical knowledge, continuity, and trust.

As observed in our case, making sense of open-source knowledge, which is openly and freely stored in GitHub and other open repositories, requires new expertise combining data science and water infrastructure knowledge. This requirement aligns with a broader shift in expertise

within the water infrastructure from construction knowledge to soft skills such as management, and IT, and the adoption of digital technologies, including smart flow meters, sensors, GIS map layers, and hydraulic models, to better understand and monitor the infrastructure.

Therefore, for the replicated knowledge to be stable and continuous, the infrastructuring of the knowledge is needed. This infrastructuring involves various aspects: first, practical knowledge must be exercised within the organisation to prevent it from being lost or fading, while also increasing trust in the open-source knowledge in practice—this constitutes a process of standardising the knowledge itself. Second, different parts of infrastructures that produce and use data need to be smoothly connected. Third, routines and guidelines are necessary to ensure regular updates and maintenance.

The requirements for knowledge to be transferred, applied, and sustained, problematise the notion of openness in Open Source and illustrate a pathway through which open-source knowledge can benefit the public. The use of Open Source in the studied water infrastructure demonstrates a manifestation of Open Science as a public good, being publicly funded and benefitting all residents who use drinking water. This echoes Cuevas-Garcia and others (2024) who argue that infrastructural work, in their case, maintenance practices, can serve as a public good.

The findings propose that for the normative or prescriptive notion of the public good in science to be realised, in the era of commercialised and patented science (Fuller 2020a; Kasavin 2020; Stengel et al. 2009), one should examine how knowledge benefits society in realms such as policy-making and public infrastructures. This suggests that the potential for knowledge to serve as a public good can be manifested through the infrastructuring of that knowledge, which means embedding and standardising it within an infrastructure.

Moreover, the narrative of experts about residents reveals that they are addressed through economic relations they have with the service-providing infrastructures and are considered either users or customers of the infrastructures. This follows other scholars' illustrations of how publics are evoked and enacted by experts (Green et al. 2025; Hetherington and Jalbert 2023; H. Peters and Landström 2022). I add to this discussion by arguing that by focusing on how infrastructures function and operate, also a public is constituted through the material flow which responds to the essential needs of people. Hence, while the narratives are important in understanding the politics of constitution of publics through infrastructures, the literature will

benefit from refocusing more on the materiality of infrastructures, to whom they provide services and how.

The research contributes to infrastructure studies by framing infrastructures in relation to the public good, moving beyond a constructivist focus on publics and a practice-level focus on infrastructure, and arguing that the imagined benefits to the public, which are tied to almost all Open Science practices, including open source, can be examined through infrastructures.

6. Concluding remarks

During the course of this PhD thesis, transparency in research, democratic participation, and benefits to the publics have been identified as central visions of Open Science. I have conceptualised these visions in relation to the perceived crises and issues of the irreplicability of scientific research, the lack of public trust in science, and the commercialisation of science.

As these crises are addressed through these visions, they reconfigure the science–society relationship through their interactions with existing infrastructures and institutions, thus necessitating critical examination of whether they substantively address these issues or merely constitute technological fixes.

This PhD thesis engages with three gaps in the literature through the conduct of case studies. Firstly, it examines how Open Science practices aim to reconfigure scientific practices and the reasons underpinning these transformations. Secondly, it explores the coordinates of Open Science initiatives situated outside scientific infrastructures and the conditions under which they sustain the vision of participation. Thirdly, it examines the notion of Open Science as a public good through a case in which Open Science is utilised within an infrastructure.

I developed an infrastructure lens following the STS tradition of infrastructure studies. This means that I examine infrastructuring efforts aimed at implementing Open Science practices and the creation and maintenance of Open Science networks in relation to existing infrastructures. The adoption of this lens is motivated both by the specific configurations of Open Science practices and by the unique insights that an infrastructural perspective provides. On the one hand, the democratisation inherent in sharing technologies, as a core element of Open Science practices, resembles features observed in standardisation processes, which stabilise networks in infrastructures (Star 1999; Bowker and Star 1999). This means that in order for practitioners of Open Science to share knowledge and information, the use of common formats, platforms, repositories, sharing technologies, or generally standardized modes of communication is required. Without this standardisation, knowledge and information cannot flow easily within Open Science networks.

On the other hand, literature on infrastructure studies offers conceptual tools to understand the flow of knowledge in infrastructures and the *infrastructuring* practices. By turning the infrastructure noun into a verb, scholars conceptualise infrastructuring as ongoing processes, namely the practices constituting infrastructures or maintaining, and remaking the existing ones

(Michael 2020; Blok et al. 2016; Nost 2022; Karasti and Blomberg 2018) which in the context of Open Science involve new badges, collaborations, standards, and classifications. These efforts and practices, while shaping new forms of exclusion, contribute to the flow of ideas and things, which is considered by some scholars as the aim of infrastructures (Larkin 2013; P. N. Edwards 2003; Castells 2011).

Developing this lens has enabled this thesis to understand visions of Open Science not merely as future-oriented narratives, but as sociomaterial enactments which constitute and reconfigure infrastructures or, alternatively, fail to become embedded within them. This section revisits the concept of infrastructure, conceptualising it as having a core notion with multiple variations. The core of infrastructure is identified as an established network closely connected to the notion of *public*. In light of this conceptualisation, this section reviews how the research questions are answered in each empirical case.

6.1. An infrastructure lens and infrastructure as a subject of study

Infrastructure has been a topic of interest in disciplines such as STS, history, anthropology, and human geography. As a concept or an object of study, infrastructure's most commonly attributed characteristics in STS are that it is sociomaterial, relational, that it has embedded standards, and that it becomes visible when it breaks down (Star 1999; Bowker and Star 1999). Building on these foundational ideas from STS, this thesis begins its analysis by distinguishing between two analytical approaches to infrastructure: one that treats infrastructure as dynamic, in a state of becoming, fluid, and incomplete; and another that views infrastructure as established, stabilised, and solid through standardisation, which consequently creates forms of exclusion.

The two approaches diverge in terms of their analytical scale and their disciplinary orientations. The former approaches infrastructure from a micro-level perspective, which renders visible practice-level changes within infrastructures. The latter tends to adopt a meso- and macro-level perspectives, focusing more on the functional and structural positioning of infrastructures within society. This point implies a rough disciplinary distinction, associated with practice-centred methods in fields such as anthropology, sociology, and STS, as opposed to methods that analyse past archives and spatial processes in history and political geography.

These two approaches are intermingled and partially overlapping. However, they differ from each other in terms of the temporality of infrastructure. In one, the focus is on becoming and a future-oriented temporality, while in the other, infrastructure is understood as established and

as embodying a past-oriented temporality, although it changes and requires maintenance. In the former, attention is directed toward how infrastructures are continually in the making, emerging through everyday practices, visions, and innovative interventions that orient them toward possible futures. For example, Blomkvist and others (2023), in their study of adding an extension to water and waste infrastructure, provide a clear illustration of this point.

In the latter, infrastructures are approached as sedimented configurations and classifications shaped by historical trajectories, where the analytical focus lies on how these inherited sociomaterial complexes persist, are maintained, and undergo incrementally transformation over time. The macro- and meso-scale view is evident in work of Edwards (2013, 8) who states that “to be modern is to live within and by means of infrastructures”.

In the case of digital technologies, the distinction becomes even more blurred, as the digital components can turn an existing infrastructure into a mode of becoming. Alternatively, digital networks and platforms themselves may exhibit traits of standardisation and infrastructuring efforts. This means that what is accepted as an established infrastructure, through the incorporation of digital solutions, innovative technologies, and the involvement of ICT actors, undergoes transformations that render it ongoing or future oriented.

During these processes, new standards are needed and shaped; new routines, and generally, new networks of actors serve to reconfigure infrastructures. In many cases, the newly introduced technologies are short-lived, which might also destabilise some aspects of these infrastructures. Regarding digital networks and platforms undergoing processes of infrastructuring, this means that standards, classifications, and networks of actors are held together in order to sustain themselves and to constitute a kind of established infrastructure. Otherwise, following Bruno Latour (1996), this can be regarded as a failure in infrastructuring.

As the empirical cases of this thesis have shown, both of these framings of infrastructure are analytically useful, and both temporalities are observed. Open Science practices were analysed as attempts to reconfigure existing infrastructures: in the case of digital participatory tools in Tehran (paper two), an already established infrastructure was so rigid that the efforts to open data and improve it at the level of practice were unsuccessful. In contrast, in the case of the deployment of open-source tools in water and waste management infrastructure in a Scandinavian city, this Open Science practice was employed to prevent infrastructural breakdown (paper four).

On the other hand, Open Science, through infrastructuring visions, is creating standardised practices, digital networks, new classifications, and forms of exclusion, as demonstrated in the case of the study on Open Science in behavioural science academic papers (paper one). Similarly, in the case of environmental citizen observatories, networks and standards were established with the aim of sustained monitoring practices. However, the paper concludes that when networks neither consolidate into infrastructures nor become embedded within existing ones, their durability and stability are threatened, which makes them vulnerable and limits them in pursuing long-term visions.

However, a very important issue in framing infrastructures through the first approach is its political implication: framing infrastructures in terms of "infrastructuring", that is, foregrounding the incomplete and ongoing aspect through which infrastructures are made, sustained, repaired, adapted, and rendered usable in practice, has naturalising effects.

In STS terms, it can recast networks as infrastructures and contribute to a narrative in which infrastructure is understood as inherently incomplete, transient, or short-lived, thereby naturalising instability and temporariness as the prevailing state of infrastructures, which may influence the concept of citizenship and how inhabitants "should" experience urban and vital services.

The problem is that, by focusing on this aspect, the structural conditions that render infrastructures incomplete may be obscured, or the conditions that cause infrastructural decay, such as public budget cuts, may be rendered marginal and irrelevant. This can take its most critical form when fluidity and incompleteness are associated with infrastructures situated in the so-called Global South context (Lemanski 2020; Guma 2025). The importance of such a narrative is that it can shape the relationship between the state and citizens and how citizenship is conceptualised in various contexts. Moreover, it can disrupt the norm of durability and stability of infrastructures as the standardised mode of providing services to the *public*. My empirical research on environmental citizen observatories (paper two) provides an example that challenges this kind of framing. The paper's argument is grounded in the distinction between networks that manifest infrastructuring traits and established, stable infrastructures. It argues that such networks, due to their short-lived and transient characteristics, cannot replace infrastructures.

In this context, digital technologies and networks can reconfigure existing infrastructures. They might destabilise them through contrasting temporalities. For example, the use of new digital

components with short temporalities might lead to more frequent maintenance. Alternatively, networks that take on the roles of established infrastructure might render existing established infrastructures unnecessary. At the science-society-government level, this could free the government or public authorities from their responsibilities or make the infrastructure dependent on transient actors and lead to mismatches in standards.

Infrastructure was developed as a theoretical lens in papers one and four and it was approached as a study object in papers two, three and four in this thesis. Thus, in this thesis, infrastructure has not been treated as a singular or static lens or concept. Rather, different variations appear in each of the cases, yet they revolve around what I argue constitutes the core of infrastructure.

I argue that the core of infrastructure, as examined through the cases, is a well-established sociomaterial network that provides flows of goods and data to the *public*. Being well-established draws on Susan Leigh Star's (1999) conceptualisation of infrastructure, where she emphasises that infrastructures embody standards and have an installed base. This means that infrastructures exist only when networks become constituted and established. At the everyday level, they undergo maintenance and transformations, and various extensions and innovations can be added to them, however, their installed bases remain relatively stable. Through processes of maintenance and change, the installed base can serve as a platform for ongoing infrastructuring efforts and trends; data and networks can be incorporated into it, or it may become subject to neglect and decay.

Building on scholars who have emphasised the notion of flow (Castells 2011; Larkin 2013; P. N. Edwards 2013), I contend that well-established networks enable the sociomaterial flow of goods, knowledge, and ideas, through which infrastructures establish a material relation and create a public who are the beneficiaries of these infrastructures. The material relation connects people as inhabitants, workers, users, scientists, local groups, or experts to the infrastructures, thereby shaping dependencies and exclusions. This public can be an exclusive group or the majority of inhabitants using an urban or a public infrastructure. I note that the term public, which is used above, has a different meaning from the term public used to refer to the ways in which infrastructure is owned, managed, and the entity to which responsibility for building, repairing, and maintaining infrastructures is assigned.

Regarding the ownership or management of infrastructures, the definition provided earlier for infrastructures might seem problematic, as many infrastructures are run by private entities and the boundary between the private sector and the public sector is blurred (Van Der Vleuten and

Kaijser 2005; Plantin et al. 2018; Hoeyer 2020). In addition, private entities create networks of interdependencies even in cases where the infrastructure is most associated with the public sector. Meanwhile, digital entities, such as platforms, have exacerbated this condition by introducing new socialities and, as Plantin and others (2018) argue, by contributing to the processes of platformisation of infrastructures.

However, the notion of "public" in infrastructure goes deeper than the question of whether the actors involved are from the public sector or the private sector: infrastructures are nonetheless sociomaterial complexes that sustain collective lives. They provide standardised flows of goods and ideas. As commercialised as they may be, they still provide essential services and shape the relationships between the state and citizens. As such, the changes in infrastructures, particularly the privatisation of infrastructures, reshape and reconfigure this relationship (Von Schnitzler 2013; Lemanski 2020; Fredericks 2018; Jennifer Gabrys 2021). This does not remove the notion of public from infrastructures; rather, it reveals transformations in the management of collective infrastructures and in how the public is sociomaterially constructed.

This is illustrated in the case of the use of open-source tools in water infrastructure (paper four), where I argue that the vision of public benefit in open-source tools can be enacted through an infrastructure, which constitutes its public through the material relations it establishes with the residents of the city. Similarly, in the case of the use of digital tools in Tehran (paper three), where the infrastructure enables the flows of reports and data, the public is both constituted through the sociomaterial relations between urban infrastructures and citizens and simultaneously imagined as actors who engage with open data.

In the other two cases, the public is largely an exclusive or imagined public. In the case of environmental citizen observatories (paper two), the public involves limited civil society groups and NGOs. However, it is argued in that paper that the lack of ties with existing infrastructure leads to vulnerabilities in Citizen Science initiatives. One speculation that can be made is that in the absence of infrastructure, the public can be constructed by hegemonic actors or imagined in a way that benefits influential or private actors.

In the case of Open Science in behavioural science (paper one), which shows infrastructuring efforts in scientific knowledge infrastructures, the public is an imagined one that witnesses Open Data and Open Research. The discussions in academic literature imagine a certain public that possesses the required skills and resources to make use of online-accessible knowledge. In other words, by not specifying the groups of public(s), it replaces infrastructures with

individuals. Consequently, the stakeholders who possess these skills and resources, such as private corporations, are the primary beneficiaries of Open Science (Kansa 2014; Mirowski 2018; "Open Source Security and Risk Analysis Report Trends | Black Duck," n.d.).

Based on this core definition of infrastructure, as a well-established sociomaterial network that provides flows of goods and data to the public, variations across the cases can be understood. The cases show variations in their degree of complexity, the involvement of different forms of labour, namely free, private, and public labour, within them, the extent to which they are infrastructured into existing infrastructures or are in the process of making their own infrastructures, and how they succeed in enacting their visions. It can be argued that the degree of complexity can be associated with the geographical scope and the heterogeneity of the actors involved. Moreover, some cases involve a large quantity of free labour; others appear to depend more on public funds for their infrastructuring efforts. This is clearly seen in the cases of open-source tools (paper four) and Citizen Science initiatives (paper two), where a great deal of labour is performed by volunteers in their free time. Another speculation is that Open Science initiatives thrive on a mixture of free labour and public labour for their establishment and durability.

6.2. Enactment of visions and reconfigurations of infrastructures

With this understanding of infrastructure and the variations in each empirical case, I return to the question of how the visions of Open Science are enacted and how they reconfigure existing infrastructures. Open Science, as an umbrella term (Fecher and Friesike 2013), is too broad both geographically and conceptually to be fully investigated in terms of whether it delivers on its promises. That is, it encompasses diverse practices, and it is locally enacted while being dispersed across various geographies. However, each empirical study demonstrates key insights into how Open Science visions reconfigure infrastructures.

In paper one, transparency was envisioned as a response to the replication crisis. The research showed that Open Science practices are expected to transform scientific practices through standardised procedures. The prescribed and realised changes in scientific practices in the studied cluster of the literature published between 2017 and 2021, although they address the perceived loss of credibility of scientific results and attempt to solve it through transparency and moral control, nevertheless reconstruct the replication issue in a narrow technical sense and propose an infrastructuring response to it. The infrastructuring response includes the suggestion and implementation of guidelines, routines, and policies, known as standardisation

and classification in STS infrastructure studies, alongside the creation of collaborations and platforms. More importantly, these new configurations cannot be established or implemented without digital sharing technologies. In this paper, we argue that Open Science, which is considered a scientific or social movement (Peterson and Panofsky 2023; Penders 2022) with certain activists, collectives, and events, resembles what Hess (2005) calls a Technology- and Product-oriented Movement (TPM). In his paper, he illustrates that when social movements are centred on the use of certain technologies, interact with existing industries, and involve private actors, they can be considered as TPMs, and he exemplifies this through two cases of solar energy and the open-source movement.

Therefore, these infrastructuring efforts by the actors involved, namely policymakers, scientists, and generally what Sabina Leonelli calls Open Science activists (Leonelli 2023; Lund 2025), are incorporated into existing scientific infrastructures through the addition of digital sharing technologies provided mostly by private entities as necessary components thereof. However, the enactment of these visions seems to be more of a technological fix to the replication crisis.

Paper two discusses the absence of infrastructure. The findings of this paper shows that participatory knowledge-making initiatives can create networks of people, guidelines, routines, through using digital sharing technologies and their local communities. However, these initiatives exhibit limitations and vulnerabilities as a result of not being anchored in an infrastructure that can set standards, produce legitimate knowledge, gain trust, and sustain them. Hence, the absence of infrastructure causes the initiatives to lack credibility and financial support, and they become vulnerable in enacting their vision of long-term monitoring. This paper focuses on the distinction, mentioned earlier, between networks and infrastructures. The distinction is based on their temporal differences and the degree of stability. While the point that infrastructures operate on a different temporality than networks (Van Der Vleuten and Kaijser 2005, 8) is not new and comes from the history of science and technology tradition, this thesis illustrates that networks might fail to achieve their long-term goals if they lack an infrastructural tie. This finding also emphasises the STS position on the importance of knowledge infrastructures in knowledge production (Sismondo 2017).

It is noteworthy to highlight the contrast between paper one and paper two regarding their relationship with scientific infrastructures, namely, the infrastructures that produce and disseminate scientific knowledge and possess scientific credibility and financial support

networks through private and public actors. In paper one, Open Science infrastructuring efforts act as a disciplining force, exercising moral control in relation to these scientific infrastructures, or as Penders (2022) articulates, as a civilising process separating reformed science from other forms of science, in which a new moral economy is constructed through bureaucratic innovations such as preregistration. In contrast, in paper two, the lack of ties with scientific infrastructures plays an important role in rendering participatory knowledge-making initiatives vulnerable. The contrast implies that the implementation of Open Science should be contextualised in relation to scientific infrastructures and also be recognised as value-laden. Without values such as public benefit in scientific infrastructures, Open Science can act as a merely technocratic and bureaucratic force, and in the absence of infrastructure, such value-laden forms of Open Science lack the capacity to sustain themselves.

Paper three showcases how transparency through Open Data, as a way to increase participation, is prescribed as a technical solution involving a series of standardisation and alignment works in an urban infrastructure. However, this solution overlooks the requirements that make the transfer of knowledge meaningful, the infrastructures that legitimise and evaluate knowledge, and the broader societal institutions that enable citizen engagement.

In paper three, the distinction between networks and infrastructure is emphasised based on the extent to which a network is constituted and established. This condition is related to standardisation and rigid classifications, which produce exclusions and obstruct the flow of knowledge in an infrastructure. In other words, although infrastructures are emphasised for their connective qualities, they embed features that impede connectivity (Van Der Vleuten and Kaijser 2005; Star 1999), or what I refer to in this paper as the flow in the infrastructure. This is illustrated in the case of participatory tools in Tehran, where adding smart technologies and Open Data as digital networks could not facilitate the flow of information due to valuation practices and the hierarchy of expertise. This paper emphasises that practice-level alignment work involving digital technologies might not result in infrastructural changes. Rather, the smart solutions and Open Data, as the case showed, left the infrastructural flow intact while adding new ICT stakeholders. The reason lies in the neglect of the embeddedness and broader politics of infrastructure, which pose obstructions to the flow of knowledge and information within the infrastructure.

It is worthwhile to note that the distinction between network and infrastructure creates theoretical and ontological complexities from an STS point of view. Regarding the theoretical

aspect, the problem is that, from the two previously mentioned framings of infrastructure, — one which emphasises *establishedness*, embedded standards, and rigid classifications, and the other that focuses on how infrastructures are incomplete, fluid, and heterogenous — the recent theorising of infrastructure as fluid and incomplete (e.g., Guma 2025; Lemanski 2020; Lawhon et al. 2023), does not distinguish between infrastructuring efforts and infrastructures, which prevents us from seeing the distinct temporalities that networks and infrastructures have. Moreover, from the two very important STS tradition of Actor-Network Theory (ANT) and post-ANT, the distinction between networks and infrastructures does not hold ontologically. In ANT and post-ANT traditions, entities are enacted within networks (for example, (Law 2013; Latour 2005)) and it is their relational ontology that constitutes them. However, Marres (2015) draws an analytical distinction between constituted and constituting ontologies. Marres's distinction helps explain that although networks might evolve into infrastructures, until they are established as such, they face limitations and vulnerabilities, and the knowledge they produce might lack legitimacy.

Paper four claims that Open Science practices can enact the vision of public benefit through intermediaries such as public infrastructures. This paper showcases a successful case of enacting Open Science visions by foregrounding the idea of the public good. It follows Callon's (1994) argument that science cannot be transferred and, in this case, made open without necessary investments in the reproduction of science, in complementary assets such as embodied skills, in maintaining these assets through databases and cloud services, and in the mobilisation of science. I argue that these requirements for open-source tools constitute an infrastructure. The case study illustrates that through the sociomaterial flow of goods and ideas provided by the infrastructure, the public is created. The public, sociomaterially constructed through their relationship with infrastructures, consists of people who use and benefit from infrastructures. This materialisation of the public corresponds to Fuller's (2020a) critique of science as a public good. He argues that since science functions for certain limited groups of people within society, it is not necessarily a public good. Rather, in his view, science is a club good. He finally concludes with the prescriptive statement that science should nonetheless be a public good.

Following the final part of his argument that science should be a public good, in paper four, I argue that the vision of public good can be enacted through a public infrastructure. Firstly, because Open Science cannot benefit the public directly; As Callon (1994) argues, to understand and make use of science, knowledge, skills, and tools are needed. Secondly, the

notion of *public* is vague and it can be constituted and evoked in favour of certain private entities and economic logics, as other STS researchers have noted (e.g., Michael 2020; Hetherington and Jalbert 2023; H. Peters and Landström 2022). In this sense, any public is constituted and constructed. Therefore, in this thesis, I suggest that a constructed public formed through the material flow of goods can be a way in which users of the infrastructure benefit from Open Science. Therefore, Open Science, when embedded within an infrastructure can become a public good: a constructed public which, although it can be manipulated through affective politics and economic logics, is less exclusive.

The first three studies can be associated with the discussion of Open Science as a social movement (Penders 2022; Peterson and Panofsky 2023) and they position Open Science practitioners, namely, scholars in paper one, citizen science teams in paper two, and policymakers in paper three, as agents of change and reform. They aim to change bad practices of science and policy and imagine a public who monitors and witnesses through these practices. However, the enactment of their visions of participation and transparency, or more broadly, of change through Open Science practices, seems to be problematic. The agents of change in each case study seem to fall short of their visions or fail to realise them: the changes advocated by scholars in paper one are constrained by the reduction of the problem to a technical definition and agenda; Citizen Science teams overlook the importance of ties to existing scientific infrastructures in addressing structural and temporal vulnerabilities; and policymakers in paper three underestimate the rigidity of the exclusions and classifications that infrastructures create.

In contrast to the first three studies, in the last one, agents of change who are part of the management team of a public infrastructure, do not pursue a radical change. While they remain committed to the notion of public benefit, they focus on the existing material flow in the infrastructure and how this service can be improved. In that way, they are part of the infrastructure and they are value laden. However, they do not seek to pursue broader political change. The obstruction in the flow, in this particular infrastructure, although adding another layer to the existing infrastructure, or in other words constituting an infrastructure within an infrastructure, does not aim to transform rigid classifications associated with broader infrastructural changes. In that sense, they succeed in integrating their vision of public benefit through Open Science practice, but wider politics become irrelevant to them.

This can suggest that the agents of change, or vision-holders, in all four cases have limited possibilities in using Open Science, and that multiple factors shape the implementation of Open Science: the first one is the vision itself and the question of why and for whom the vision is being pursued. This technical or bureaucratic definition of Open Science might not ultimately align with the Open Science visions of replicability, participation, or public benefit. Indeed, the value-laden aspect of Open Science is crucial to Open Science in its practice, as it prevents the reduction of Open Science to technocratic solutions or the disregard of the political dimensions involved in its implementation.

The second factor is the critical role of infrastructure in the enactment of Open Science visions of participation, public benefit, and transparency. The three visions, situated at the intersection of public, policy, and science, require infrastructures in order to be realised. I argue that the agents of change or vision holders in the first three studies seem to miss their objectives or fail to realise them: paper one (mixed-method analysis on a cluster of published articles on Open Science) does so by disregarding the political and social aspects of infrastructure and by defining the problem of replication in a narrow technical sense; paper two (comparing cases of environmental citizen observatories) does so by overlooking the importance of scientific infrastructures in addressing structural and temporal vulnerabilities; paper three (study of participatory tools in Tehran) through underestimating the classifications and exclusions imposed by the structural politics of infrastructures. The final paper, however, showcases a successful enactment of the Open Science vision of public benefit, which has been pursued within an infrastructure.

The infrastructure lens complements our understanding of shortcomings in the implementation of Open Science practices and helps Open Science practitioners to enact their visions of participation, public benefit, and transparency. These insights derive from the sociomaterial framing of infrastructure, its recognised characteristic of connecting various micro-, meso-, and macro-scales, and the notion of *public* inherent in it. The lens is especially helpful for Open Science because of the crucial digital components, such as sharing technologies in its practices, which are sometimes reductively presented as key enablers of change in science and policy. By developing this lens to study Open Science, this thesis does not aim to approve or reject these visions. Rather, through the infrastructural lens, and by centring the notion of *public* in infrastructure, this thesis identifies public benefit as the most important vision for Open Science, one that can also advance other visions.

7. References

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