IOI

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Defining Open Scholarly Infrastructure

Preliminary Investigation

20 April 2022

1. Background

Invest in Open Infrastructure (IOI) was founded on the premise that open, community-owned infrastructure is necessary for scholarly research to thrive.

We are certainly not alone in this sentiment. Numerous organisations across the scholarly research ecosystem, including the Ford Foundation, the Scholarly Publishing and Academic Resources Coalition (SPARC), the Global Sustainability Coalition for Open Science Services (SCOSS), and the Association of Research Libraries (ARL), as well as many others[a][b][c] have recognized the critical role open infrastructures play for the communities they serve — contributing to more equitable, accessible, and resilient knowledge practices.

IOI strives to build on the efforts of others working to improve funding and resourcing for the open infrastructure on which scholarly research relies. One way we hope to achieve this is by pushing the limits of our current understanding about infrastructure in scientific research and scholarly communication. A deeper understanding will have significant implications for how we collectively engage with and support the organisations providing services that make research and scholarship possibl[d]e. This report represents the beginning of an iterative process for IOI in deepening its understanding on this topic that we look forward to developing and refining as our work progresses.

2. What is the problem?

To ensure its stakeholders understand the essence and scope of IOI's work, IOI produced in late 2019 a working definition of both "infrastructure" and "open infrastructure" in the context of the scholarly research ecosystem. It reads as follows:

> By "infrastructure" we mean the sets of services, protocols, standards and software that the academic ecosystem needs in order to perform its functions throughout the research lifecycle — from the earliest phases of research, collaboration and experimentation through data collection and storage, data organisation, data analysis and computation, authorship, submission, review and annotation, copyediting, publishing, archiving, citation, discovery and more.

> "Open infrastructure" is the narrower sets of services, protocols, standards and software that can empower communities to collectively build the systems and infrastructures that deliver new improved collective benefits without restrictions, and for a healthy global interrelated infrastructure system.

Unfortunately, this two-part definition:
1. Is unsystematic[e] (both in breadth and depth) in delineating the kinds of functions and activities scholarly infrastructure needs to support,
2. Is vague in defining the values and goals of "open infrastructure", and,
3. Does not easily translate to a robust theoretical framework that can provide structure and support to IOI's varying projects.[f]

3. What is IOI doing about this problem?

This preliminary report outlines IOI's initial attempt towards a more sophisticated framework for understanding open infrastructure for research and scholarship. Such a framework will:

1. Facilitate the development of a systematic and standardised[g][h] *definition* of open infrastructure that mediates the gaps in our current definition while effectively delineating and communicating the essence and scope of our work.
2. Inform the design of our research methods for examining open infrastructure across our varying projects[1] — establishing proven constructs, concepts, and approaches on which we can draw.

For this report, we examined a body of literature that includes works across the fields of anthropology, scholarly communications, international development studies, science and technology studies, and infrastructure studies. We aimed to balance foundational understandings of open infrastructure with both recent and peripheral discussions on the topic.[i][j]

We reviewed, categorised, and annotated this compiled literature in order to develop: [k]

1. An initial assessment of the current state of research on the topic of open infrastructure,
2. Recommendations for the ways in which IOI's working definition of open infrastructure can be strengthened and,
3. Recommendations for future areas of development and further research for better understanding open infrastructure.

This report is not an exhaustive inventory of literature that attempts to engage with theoretical or practical conceptions of open infrastructure across the social sciences[1]. Instead, this report is a work in progress that will gain breadth, depth, and nuance over time. For more detail on future iterations of this literature review, please refer to Section 6.

This report is divided into three sections:

1. First, we review our curated body of literature in order to outline prevailing conceptualizations of open infrastructure in the context of research and scholarship. We provide categories to better understand the ways in which "infrastructure", "scholarly infrastructure", and "open scholarly infrastructure" have each been conceptualised and defined.[2]
2. Second, we synthesise this literature, identifying key takeaways for IOI when conducting its own investigations into open infrastructure for research and scholarship.
3. Lastly, we outline recommendations for future areas of development and further research to better understand and best support open infrastructure.

4. Key Elements from the Literature

4.1. How have others defined "infrastructure"?[m][n]

In the digital age, the term "infrastructure" has been used to refer to the "constellations of software technologies and systems usually associated with the Internet" (Karsati et al., 2010, p. 382). With the proliferation of work around this topic, terms such as "information infrastructure", "cyberinfrastructure", "e-infrastructure", and "knowledge infrastructure" have been coined to reflect the distinct frameworks and empirical breadth applied within inquiries into this broad phenomenon.

Our intention in this report is to capture all these varying conceptualizations and we use the all-inclusive term "infrastructure" as a catch-all that encompasses this diversity. However, this preliminary investigation engages to a greater extent with the literature on "information infrastructure" as we wanted to prioritise theoretical approaches that considered both the social and technical dimensions of infrastructure. [o]

In the literature we reviewed, definitions of "infrastructure" (summarised in Table 1, below) often frame the concept as a network (see especially Larkin, 2013). Infrastructure is described as consisting of disparate entities — both technical (hardware and software) and social (practices, norms, and structures) — that as an ensemble, facilitate the linking and/or movement of ideas, signals, objects, and people (Larkin, 2013).

Definition	Author(s)	Research Discipline[p]

Definition	Author(s)	Discipline
Cyberinfrastructure refers to a "layer of enabling hardware, algorithms, software, communications, institutions, and personnel. This layer [provides] an effective and efficient platform for the empowerment of specific communities of researchers to innovate and eventually revolutionize what they do, how they do it, and who participates."	Atkins et al., 2003 (p. 5)	Cyberinfrastructure
e-Infrastructure refers to "in the first instance to designate the physical or material components of [a large] technological system, the advanced electronic networks that make use of the Internet and the Web, as well as, secondarily, the organizational networks that are supported by this system."	Schroeder, 2007 (p. 2)	e-Infrastructure
"Superadded to the term 'information,' infrastructure refers loosely to digital facilities and services usually associated with the internet: computational services, help desks, and data repositories to name a few."	Bowker et al., 2010 (p. 98)	Infrastructure Studies; Information Infrastructure
Knowledge infrastructure refers to the ''robust networks of people, artefacts, and institutions that generate, share, and maintain specific knowledge about the human and natural worlds."	Edwards, 2010 (p. 17)	Infrastructure Studies; Knowledge Infrastructure
"Infrastructures are built networks that facilitate the flow of goods, people, or ideas and allow for their exchange over space. As physical forms they shape the nature of a network, the speed and direction of its movement, its temporalities, and its vulnerability to breakdown. They comprise the architecture for circulation, literally providing the undergirding of modern societies, and they generate the ambient environment of everyday life."	Larkin, 2013 (p. 328)	Anthropology

Table 1: Definitions of Infrastructure Across Varying Research Disciplines

In these frameworks, infrastructure is described as a "supporter" or "enabler", "sinking into the background" and becoming visible only when it breaks down[q][r][s][t][u][v] (Star & Ruhleder, 1996, p. 112). Because of this tendency to fade into the background[w][x][y], infrastructure can appear unremarkable and unexciting in nature (Karasti & Blomberg, 2018; Star & Ruhleder, 1996).[3]

Science and Technology Studies (STS) embraces this boringness[z][aa][ab][ac] — "foregrounding the truly backstage elements" of the mundane, background practices and unnoticed work (of designers, developers, users, managers, and mediators just to name a few) that facilitate the functioning of infrastructure (Star, 2002, p. 16) (refer to Table 2, below).

Definition	Author(s)	Discipline
Infrastructure emerges in relation to organised practices. It "occurs when local practices are afforded by a larger-scale technology, which can then be used in a natural, ready-to-hand fashion."	Star & Ruhleder, 1996 (p. 114)	Ethnography; Knowledge Management; Information Systems
"Following Star and Ruhleder (1996), an infrastructure emerges when it reaches beyond a single event on a temporal scale or a single site practice on a spatial scale [...occurring] when here-and-now practices are	Karasti et al., 2010 (p. 400)	Information Architecture; Science and Technology Studies

afforded by temporally extended technology that can be used in an everyday, reliable fashion. Infrastructure becomes transparent when it exists as an accessible, ready-to-hand installed base that enables envisioning future usages."

Table 2: Conceptualization of Infrastructure as Related to Organisational Practice

The field of STS[ad][ae], therefore, understands infrastructure not just in terms of interdependent components of a network but also in terms of "configurations" of practices and activities (Karsati et al., 2010; Star & Ruhleder, 1996). Popularised by Star & Ruhleder (1996), such a framework shifts understanding of infrastructure from being static and definitive ("what infrastructure is") to dynamic and relationally configured ("we can't be definitive about what infrastructure is, but rather in the ways infrastructure emerges") (Bowker et al, 2010; Karsati et al., 2010; Star & Ruhleder, 1996).

This marks a significant shift towards the study of infrastructure's specific dimensions and characteristics, resulting in the concept most often being "defined by jotting down a laundry list of characteristics" (Bowker et al., 2010, p. 99) (summarised in Table 3, below).

Characteristics of Infrastructure	Author(s)
The configuration of the following nine (9) dimensions form 'an infrastructure': (1) Embeddedness (2) Transparency (3) Reach or scope (4) Learned as part of membership (5) Links with conventions of practice (6) Embodiment of standards (7) Built on an installed base (8) Becomes visible upon breakdown (9) Is fixed in modular increments, not all at once or globally	Star & Ruhleder, 1996
Based on a synthesis of characteristics emerging in prominent literature, infrastructures can be characterised by the following five (5) dimensions: (1) their profoundly relational quality (2) their intrinsic (at least partial) invisibility[af][ag][ah][ai][aj] (3) their connectedness, sometimes described as "scaling"[ak][al] (4) their emerging and accreting quality of infrastructures (5) the role of intentionality and intervention in delineating infrastructures	Karasati & Bloomberg, 2018
Infrastructures have a "modular, multi-layered, rough-cut character [...]. [They] are not systems, in the sense of fully coherent, deliberately engineered, end-to-end processes. Rather, infrastructures [...] consist of numerous systems, each with unique origins and goals, which are made to interoperate by means of standards, socket layers, social practices, norms, and individual behaviors that smooth out the connections among them. This adaptive process is continuous, as individual elements change and new ones are introduced — and it is not necessarily always successful."	Edwards et al., 2013 (p. 5)
"Information infrastructures are characterised by openness to number and types of users (no fixed notion of "user"), interconnections of numerous modules/systems (i.e. multiplicity of purposes, agendas, strategies), dynamically evolving portfolios of (an ecosystem of) systems and shaped by an installed base of existing systems and practices (thus restricting the scope of design, as traditionally conceived). Information	Monteiro et al, 2013 (p. 576)

infrastructures are also typically stretched across space and time: they are shaped and used across many different locales and endure over long periods (decades rather than years)."

Table 3: Characteristics of Infrastructure Identified by Various Authors

4.2. How have others defined "scholarly infrastructure"?

In this report, we use the term "scholarly infrastructure" to refer to infrastructures that are specifically associated with research and scholarly knowledge production. Across the literature reviewed, this phenomenon has also been referred to as "scholarly communication infrastructure", "scholarly publishing infrastructure", "e-research infrastructure", and "knowledge infrastructure"[am][an][ao] — each reflecting a distinct framework and empirical breadth.[4]

The definitions of scholarly infrastructure that we reviewed (summarised in Table 4, below) utilise the popular metaphors of infrastructure as a "supporter" or "enabler", describing the phenomenon as the thing upon which the scholarly knowledge production and dissemination — or its particular components — operate. These definitions also often frame scholarly infrastructure as a network[ap], describing it as a system that pulls diverse actors, organisations, and perspectives across domains, disciplines, and geographies together to engage in common practices.

Definition	Author(s)
"e-Research infrastructures are networked systems in which technologies and social institutions are intertwined, [combining] extensive networks of physical artefacts with the organizational capacity to implement and sustain them. [...They are] both: a large technological system insofar as they consist of a number of interdependent social and technical systemic parts (and large because the system covers the globe); and an infrastructure insofar as it supports research."	Schroeder, 2007 (p. 8)
The "fundamental substrate upon which scholarly research operates [...] seamlessly and successfully supporting knowledge work".	Lagoze et al., 2015 (p. 1054)
The "tools and services that underpin the scholarly research life cycle".	Chen et al., 2019 (p. 1)
"Technological infrastructure that runs scholarly communication and publishing."	Maxwell et al., 2019 (p. 6)
"Infrastructure vital to the advancement of the sciences".	Watkinson & Pitts, 2021 (para. 1)
Scholarly communication technologies "includes tools, platforms, and standards that can be locally adopted to support one or more of functions of the lifecycle of scholarly communication, which is conceptualized as including the following activities: creation, evaluation, publication, dissemination, preservation, and reuse."	SComCaT, n.d. (para. 3)

Table 4: Definitions of "Scholarly Infrastructure"

Furthermore, we found numerous studies that describe scholarly infrastructure by centering the practices of individuals and/or organisations[aq][ar][as] within the scholarly knowledge production process (Chen et al., 2019; Kramer & Bosman, 2017; Lewis, 2020). These works

mirror understandings of infrastructure common within the field of STS: as emerging in relation to organised practices and connected to particular activities.

For example, Chen et al.'s (2019) investigation into the vertical integration of scholarly infrastructure first outlined the stages of the academic knowledge production process (see Figure 1, below) and then charted varying scholarly tools and services across these stages.
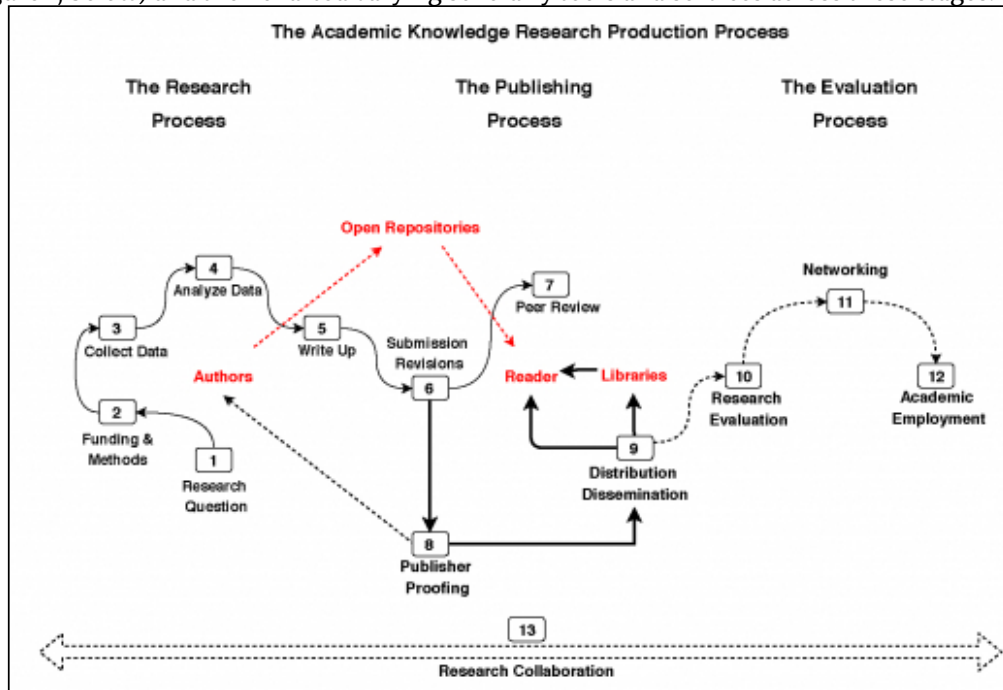

Figure 1: The Academic Research Knowledge Production Lifecycle by Chen et al. (2019)

Furthermore, both Kramer and Bosman (2017) and Lewis' (2020) works in identifying tools, services, and systems that make up the scholarly infrastructure ecosystem involved a similar approach. These authors first identified a typical workflow for scholarly research[at][au] and then classified observed tools and services based on their position within the authors' respective workflows (see Figure 2 and Figure 3 below).

Research Phase Number	Research Activities (30)	Research Phases (7)
0	project management	preparation
1	crowdsource/ define research priorities/ ideas/ collaborations	
2	fund get contract	
3	search (lit/data/patents/code)	discovery
4	get access	
5	get alerts/get (reading) recommendations	
6	reference management	
7	read/view	
8	annotate/tag (during/after reading)	
9	experiment & collect/mine/extract data	analysis
10	share notebooks/protocols/workflows	
11	analyze	

12	visualize	writing
13	write (+ code)	
14	cite	
15	translate	
16	archive/share code	publication
17	archive/share data/video	
18	archive/share publications	
19	archive/share posters	
20	archive/share presentations	
21	present research findings	
22	peer review and comment/recommend (pre-pub)	
23	select journal to submit to	
24	publish	
25	outreach/valorization	outreach
26	researcher profiling (& social network)	
27	comment	assessment
28	peer review (post-pub)	
29	measure impact (of output, e.g. article)	
30	assessment (of researcher/research group)	

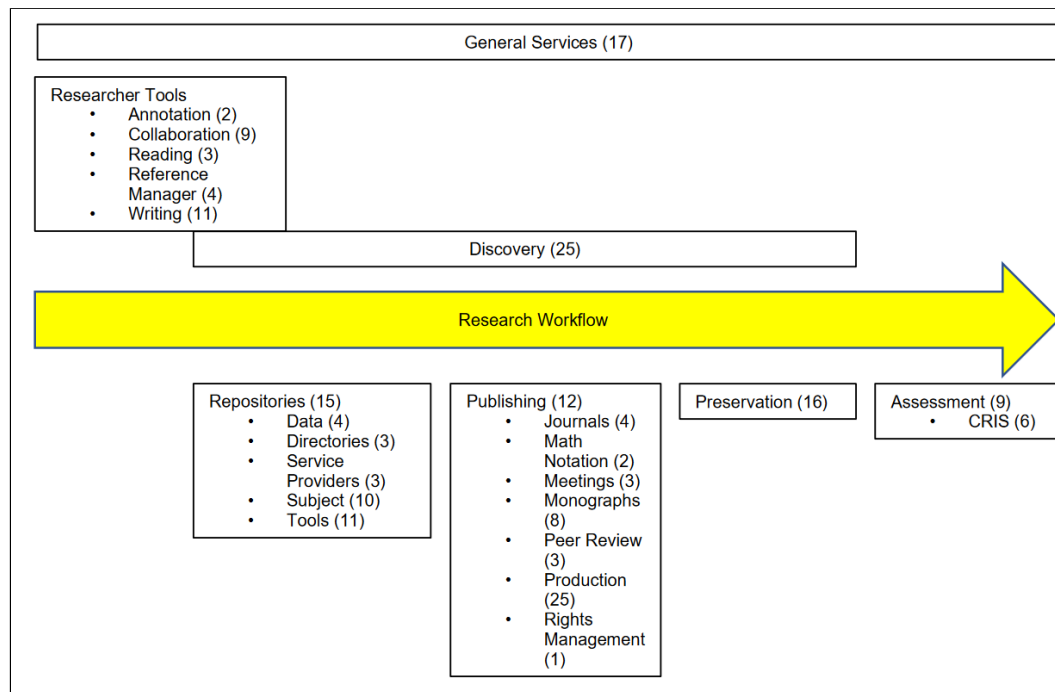**Figure 2:**[av] Research Workflow Phases adapted from Kramer & Bosman (2017)

Figure 3: Research Workflow Developed as Part of the Lewis' (2020) Bibliographic Scan of Digital Scholarly Communication Infrastructure

4.3. How have others defined "open scholarly infrastructure"?

In this report, we use the term "open scholarly infrastructure" to refer to scholarly infrastructure that is owned and/or operated[aw] by non-commercial actor[ax]s, such as academic libraries, consortia, professional associations, communities of practice, independent non-profit organisations, and other research bodies. Across the literature reviewed, this phenomenon has also been referred to as "open infrastructure", "open science infrastructure", "open common infrastructure", "community infrastructure", and "community-owned infrastructure" — each reflecting a distinct framework and empirical breadth.

Definition	Author
Infrastructure that is "trusted and relied on by the broad community it serves."	Bilder et al., 2015 (para. 4[ay][az])
"Projects that provide software or services that support open scholarship."	Lewis et al., 2018 (para. 5)
"'Academy-owned' and 'academy governed' tools, platforms, and services".	Skinner, 2019 (para. 6)
"The structures and services needed for Open Science/Scholarship to operate, e.g. services, protocols, standards and software that the academic ecosystem needs in order to perform its functions during the research lifecycle."	Ficarra et al, 2020 (p. 10)
"Open science infrastructures refer to shared research infrastructures (virtual or physical, including major scientific equipment or sets of instruments, knowledge-based resources such as collections, journals and open access publication platforms, repositories, archives and scientific data, current research information systems, open bibliometrics and scientometrics systems for assessing and analysing scientific domains, open computational and data manipulation service infrastructures that enable collaborative and multidisciplinary data analysis and digital infrastructures) that are needed to support open science and serve the needs of different communities."	UNESCO, 2021 (p. 12)
"In an Open Science context, 'infrastructure' — the 'structures and facilities' — refers to the scholarly communication resources and services, including software, that we depend upon to enable the scientific and scholarly community to collect, store, organise, access, share, and assess research."	SCOSS, 2022 (para. 2)

Table 5: Definitions of "Open Scholarly Infrastructure"

Works that directly explore open scholarly infrastructure or its derivatives often draw from two different frameworks.

Many — often earlier — works examining this phenomenon draw from the extensive literature on "open source", focusing on the ways in which software, standards, and protocols can promote the accessibility or transparency of infrastructure development, maintenance, and services (Schroeder, 2007; West & O'mahony, 2008). More[ba][bb][bc] recently, there has been a shift towards a framework that draws from political economy, instead focusing on the threat of enclosures to community-owned and -operated scholarly infrastructure[bd] (see for example, Skinner, 2019; Moore, 2020). As Bilder et al. (2015) note:

We believe we risk repeating the mistakes of the past, where a lack of community engagement lead[s] to a lack of community control, and the locking up of community resources. In particular our view is that the underlying data that is generated by the actions of the research community should be a community resource – supporting informed decision making for the community as well as providing [a] base for private enterprise to provide value added services.

While these frameworks draw from different theoretical traditions, both regard infrastructure and its disparate parts beyond commodity production — their valuation existing beyond the logic of the market. In this sense, open scholarly infrastructure functions not just in support of productive practices around scholarship and research, but also in support of social practices and values as well (Helfrich, 2013, as cited in Heinrich Böll Foundation et al., 2013). Some of the explicit values that open scholarly infrastructure has been envisioned to support[be][bf] can be found in Table 6, below.

[bg][bh]

Values for Open Scholarly Infrastructure	Author
Infrastructure that is characterised by "unrestricted access and use, being free of charge to users, and using non-exclusionary (open) standards."[bi]	Schroeder, 2007 (p. 2)
Governance • Coverage across the research enterprise • Stakeholder-governed • Non-discriminatory membership • Transparent operations • Cannot lobby • Living will • Formal incentives to fulfil mission and wind-down Sustainability • Time-limited funds are used only for time-limited activities • Goal to generate surplus • Goal to create contingency fund to support operations for 12 months • Mission-consistent revenue generations • Revenue based on services, not data Insurance • Open source • Open data (within constraints of privacy laws) • Available data (within constraints of privacy laws) • Patent non-assertion	Bilder et al., 2015
Infrastructure that "deliberately allow[s] for multiple forms of participation amongst a diverse set of actors, and which purposefully acknowledge[s] and seek[s] to redress power relations within a given context."	Okune et al., 2019 (p. 2)

Table 6: Values for Open Scholarly Infrastructure

5. Key Takeaways for IOI

To better grasp the fundamental characteristics of infrastructure, we synthesised the characteristics/dimensions defined in the literature we reviewed — paying particular attention to overarching themes and points of contention. From this synthesis, we identified practical considerations IOI should make when conducting its own investigations into open infrastructure for research and scholarship.

(1) Infrastructure serves a function

In the conceptualization of infrastructure by Star and Ruhleder (1996), infrastructure emerges in relation to organised practices. When a cook is preparing dinner, for example — washing ingredients and boiling water — the water system emerges as infrastructure. [bj]In this regard, infrastructure's function is to facilitate (or support) the carrying out of different activities, particularly when: (1) these activities require coordination or agreement, (2) these activities are valued as basic "rights", and (3) these activities are so widespread that it doesn't make sense to provision infrastructure individually (Helfrich, 2013, as cited in Heinrich Böll Foundation et al., 2013).

However, many authors have also noted the function of infrastructure beyond supporting productive organisational practices. Numerous case studies across anthropology, politics, and sociology, for example, point to the intrinsic link between "infrastructure" and "modernity" (Larkin, 2013). Most of these case studies — examining traditional "brick and mortar" infrastructures — demonstrate how their function is not just related to organisational activities. Infrastructure, in these instances, also embodies political address — promoting larger ideas and sentiments, related to nationalism (Dalakoglou, 2010), post-colonialism (Harvey & Knox, 2012), and communism (Humphrey, 2005).

Bottom line for IOI: When considering open infrastructure, IOI should be mindful of not just the productive functions it serves in supporting/facilitating[bk] knowledge practices *but also* its aesthetic and ideological functions as well. [bl][bm][bn]

Questions to consider should include:
- What organisational and/or political experiences does open infrastructure produce for its users[bo][bp]? Are these experiences different from the experiences produced by commercially-run and -operated infrastructure?
- What emotional values or symbolic meanings are tied to open infrastructure?
- How does the design of open infrastructure's development, maintenance, and operations impact its productive, aesthetic, and ideological functionalities?
- How do the different communities within the open infrastructure landscape understand and rationalise the various functions of open infrastructure?

(2) Infrastructure is a socio-technical system rather than a technical product[bq][br][bs]

There is a "conceptual unruli[ness]" to infrastructure that can be attributed to the fact that it is simultaneously a "thing" and the "relation between things" (Larkin, 2013, p. 329). Infrastructure is often identified as fixed objects and physical structures, but it is in fact its relational characteristic — connecting disparate entities and facilitating flows — that renders it "an infrastructure" (Larkin, 2013; McArthur, 2019; Star & Ruhleder, 1996).

Developing this idea further, a popular approach taken by STS scholars is to emphasise the practices of people in relation to technical structures. With this approach, understandings of infrastructure broaden from mere technical products to also include dynamic configurations of communities and organisations[bt][bu] as well (Karasti & Blomberg, 2018). Infrastructure, in this sense, is a complex socio-technical system instead. Bowker et al. (2010) therefore urge "movement beyond seeing the social, organizational, and cognitive sitting somehow on top of or beside the wires and gateways of the physical infrastructure. Each layer is riven[bv] [bw] through with each of these dimensions" (p. 113).

The category of STS literature following Star and Ruhleder's (1996) framework emphasises, for example, that infrastructure shapes but is simultaneously shaped by "the conventions of a community of practice" (Karasti & Blomberg, 2018; Star & Ruhleder 1996, p. 113). Infrastructure, Star and Ruhleder (1996) suggest, is intricately linked to social practices in complex ways — pointing to the ways in which the cycles of work throughout a day affect and are affected by electric power rates and needs.

In a more recent attempt to apply STS theories to infrastructure challenges in the global South, Furlong (2014) emphasises on the role the interests and power relations of political-economic actors play — in conjunction with everyday organisational practices — in shaping what he

refers to as infrastructures in a state of "malfunction" and "disrepair". He provides the example of local councillors in India acting as private water vendors, "their conflicting economic and political interests inhibit[ing] the improvement of water supply" (p. 145).

Bottom line for IOI: When investigating scholarly infrastructure, it would be a mistake to only consider its technical components. Connected to the design, development, and operation of these technical components are larger social processes[bx][by] (community practices, norms, standards, and values) that infrastructure reinforces and replicates. A successful infrastructure is one able to complement and enhance the organisational and cultural practices [bz][ca]of its users[cb][cc][cd], not just provide a technical solution to a particular need.

Questions to consider in our work should include:
- What social forms, practices, and institutions are linked to the development, maintenance, and operation of open infrastructure? In what ways do they facilitate, shape[ce], or accompany[cf] these infrastructural processes?

[cg]
- Which technical or social decisions[ch][ci][cj] about infrastructure-design, -development, or -enactment contribute to the "success" or "failure" of an open infrastructure?
- What is the relationship between these technical and social decisions (e.g. are they in conflict or in alignment, are they in a dialectic relationship)?
- Do technical changes in open infrastructure cause social changes? If yes, how does this affect power distribution/dynamics within the open infrastructure landscape?

(3) Infrastructure is dynamic

There is no "one way" for infrastructure to be created or formed. Instead, many authors within STS describe infrastructure formation as being characterised by uncertainty, "including the heterogeneous processes of becoming and the associated temporal complexities full of ups and downs, false starts, disconnects, dead ends and failures" (Karasti & Blomberg, 2018, p. 239).

Infrastructure formation is thus incremental and contiguous, emerging over the long-term and affixing onto an already existing world — of tools, practices, and roles — that both enable and limit its form (Edwards et al., 2007; Karasti & Blomberg, 2018; Star & Ruhleder, 1996). This prolonged and iterative process means that infrastructure is continuously emerging: individual elements change while new ones are introduced — with varying levels of success (Edwards et al., 2013).

The concept of "infrastructuring" was developed by STS scholars struggling with conducting empirical work on "emerging infrastructures" (Karasti & Blomberg, 2018; Star & Bowker, 2002). The fact that infrastructure is continuously emerging often makes it difficult (if not impossible) to foresee all the relevant issues that can occur. Infrastructuring demands the production of stability via ongoing monitoring, development, and maintenance [ck][cl][cm][cn] — ensuring issues are mediated as they are discovered accordingly.

If infrastructures are not attended to[co][cp][cq][cr] then "the ineluctable pull of decay and decline set in and infrastructures enter the long or short spiral into entropy that – if untended – is their natural fate" (Jackson, 2015, para. 4). Infrastructuring, thus, urges scholars to put an emphasis on the often undervalued and invisible[cs][ct][cu] ongoing work of infrastructure monitoring, development, and maintenance (Bowker et al., 2010).

Bottom line for IOI: IOI should aim to develop sensitivities towards, and tools and methods for investigating the dynamic processes[cv][cw][cx] of infrastructure. It should do this in a way that enables robust and systematic analysis while preserving and recognizing the phenomenon's ongoing, uncertain, and dynamic qualities.

Questions to consider in our work should include:
- What existing systems and processes[cy][cz] is open infrastructure built upon? What are people's[da] relationships with this "base" (e.g. do they embrace the system or want to replace it)?
- In what ways do these systems and processes[db][dc][dd] impact open infrastructure's form and function? How do they accommodate for the integration of new technologies, communities, and practices?
- What relations and processes[de][df][dg] facilitate the stability of open infrastructure?
- How can IOI best support the dynamic characteristics of open infrastructure while ensuring scarce resources in this space aren't wasted or poorly utilised?
- In what ways does the processual (and ongoing) design, development, and operation of open infrastructure contribute to its [dh][di]invisibility?

- What existing practical or conceptual methods can we use to make open infrastructure and its dynamic qualities[dj],[dk] visible in our work?

(4) Infrastructure operates at different scales, both temporally and spatially

Infrastructure is large in scale, existing as a constellation of interdependent technical and social phenomena dispersed and distributed not just across space but also across time (Star & Ruhleder, 1996). A city-run water treatment plant emerges as infrastructure when connected to a distribution line that can transport treated water to individuals across the city not just in the present but also the future — considerations having been made for its future repair as well as for potential future changes to the larger water system (Karasati et al., 2010). The key to any infrastructure, as such, "is its ability to permit the distribution of action over space and time" (Bowker et al., 2010, p. 103).

Across the STS literature we reviewed it is generally maintained that disparate technical and social phenomena become connected via the embodiment of standards — "plugging into other infrastructures and tools in a standardised fashion" (Star & Ruhleder 1996, p.113).

It is through these standards that infrastructure exists both in the local and the global contexts, where different local practices "are afforded by larger-scale [global] technology, which can then be used in a natural, ready-to-hand fashion" (Star & Ruhleder, 1996, p. 114). It is also through these standards that infrastructure exists in the short-term and long-term — when "here-and-now practices are afforded by temporally extended technology that can be used in an everyday, reliable fashion", enabling the envisioning of future usages (Karasati et al., 2010, p. 400). It's the existence of global standards, for example, that allows for water pumping equipment to be manufactured in Germany and sold on the open market to water utilities in Brazil to meet the particular needs of a local population living in the Amazon. [dl]

Bottom line for IOI: When identifying open infrastructure in its investigations, IOI should put more emphasis on systems that are or have the ability to become "large" in scale,[dm][dn] h[do] [dp]aving the potential to work in both the local and global contexts, as well as in short-term and long-term timeframes through the implementation of recognized standards. Furthermore, IOI's investigations shouldn't ignore the role of standards and standard-setting in the development and operations of open infrastructure, but seek to encourage the development, adoption, and regular improvement of standards covering operations, governance, service delivery, community engagement, and other key facets of infrastructure design, development, and operation.

Questions to consider in our work should include:
- What relations and processes allow for the ongoing "growth" of open infrastructure over time[dq][dr] and space?
- Do existing standards meet the technical and social needs of the research and scholarly[ds] communities?
- What additional standards can and should be created to exemplify the values, norms, and practices of the various research and scholarly communities[dt][du] these services support?

(5) Infrastructure is not neutral

Considering the fact that infrastructure is as much a social as it is a technical system (see Key Takeaway 2, above), there are technical as well as cultural, political, economic, and ethical[dv] [dw] choices made throughout its design, development, and operation (Clarke and Star, 2008; Star, 1999).

The larger an infrastructure is in scale, the more heterogeneous identities, abilities, needs, experiences, and goals it embodies, often leading to conflict and ambiguity (Star, 1999). Deliberate or accidental design choices can have implications depending both on whose interest and worldviews underpins a particular infrastructure, resulting in particular groups being underserved or not served at all by a particular infrastructure[dx][dy] (Karasati, 2014; Okune et al., 2019). Numerous case studies examining water systems infrastructures in the Global South, for example, have underscored the importance of historic colonial and contemporary forms of discriminatory planning in affecting access to essential water

infrastructure services for marginalized communities (Kooy & Bakker, 2008; Swyngedouw, 2004).

Similarly, in their exploration of the design and use of knowledge infrastructures for equitable participation in open science practices, Okune et al. (2019), emphasise that not all users of an infrastructure may benefit equally from its installation. An infrastructure may in fact "replicate and reinforce the gendered, raced, and other socio-political imbalances that exist within existing systems of knowledge production" (Okune et al., 2019, p. 6).

Bottom line for IOI: When investigating scholarly infrastructure, IOI needs to be mindful of the fact that power and authority are intimately distributed across infrastructural entanglements. The open infrastructure IOI investigates and engages with embodies and legitimises particular social, political, and economic values.

Furthermore, IOI needs to be cognizant of the fact that as an actor within the open infrastructure landscape, our own work can potentially be exclusion-generating and power-distributing. As an organisation, we should acknowledge the diversity and uniqueness of infrastructures[dz][ea] across the scholarly research ecosystem, and advocate for the development and spread of open infrastructures that account for alternative practices, abilities, and ways of knowing. Most importantly, IOI needs to be open to reflecting on its values and practices within this landscape, mindfully course-correcting when necessary.

Questions to consider in our work should include:
- How can IOI determine if an open infrastructure is not neutral[eb][ec][ed][ee][ef]? What are the markers/indicators of bias?
- Whose practices, abilities, and ways of knowing most influence the design, development and operation of open infrastructure? Whose practices, abilities, and ways of knowing are minimised, ignored, or silenced[eg][eh]?
- In what ways does open infrastructure replicate and/or reinforce existing knowledge and socio-economic[ei][ej] inequities?
- In what ways can IOI be an effective ally to communities working on open infrastructures in niches that aren't well served[ek][el]?

6. Areas for further work

The following are additional questions or areas of research for IOI to consider in understanding open infrastructure:

- We should expand the breadth of this literature review to better include conceptualisations of infrastructure outside of the more prominent "information infrastructure" literature we reviewed here[em][en]. Potential areas for a more holistic understanding of open infrastructure include:[eo] (1) technical frameworks for infrastructure (e.g. cyberinfrastructure), (2) political economic frameworks for infrastructure (e.g. commons enabling infrastructure), and (3) intersectional frameworks for infrastructure (e.g. inclusive infrastructure, feminist infrastructure[ep][eq]).
- Somewhat pressing, is our need to develop theoretical and practical approaches to our open infrastructure work. IOI should expand on this literature review in depth by further reviewing existing STS approaches to studying and understanding infrastructure [er]and by adapting them for open infrastructure contexts[es].
- It's clear from the literature we reviewed that open infrastructure is intimately related to the scholarly knowledge and research practices of individuals and organisations. In order for us to better understand the broad range of productive functions offered by open infrastructure, IOI should map out these practices and create a comprehensive and robust knowledge production and dissemination workflow. Ultimately, this work can inform the creation of a standardised taxonomy for productive infrastructure functions[et][eu].
- This review also makes clear that the distinguishing feature between open infrastructure and its commercially-run and -operated counterparts[ev] is the fact that it's valuated not just based on its ability to support productive functions but social practices and values[ew][ex][ey] as well. IOI should explicitly identify these values.[ez][fa]

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[1] The framework described in this report will directly contribute to our Costs of Open Infrastructure project, enabling us to identify the critical providers of open technologies and systems that support research and scholarship.
[2] These categories emerged organically as we coded our compiled body of literature. We ultimately decided that they offered the most precise classification system while simultaneously facilitating an easy-to-follow narrative for our report.

[3] While there can be an invisible quality to infrastructure[fd][fe], this invisibility is neither perpetual or constant (Karasti & Blomberg, 2018). Larkin (2013), instead describes the visibility of infrastructures as existing on a spectrum, ranging from "unseen to grand spectacles and everything in between" (p. 336).

[4] Terms such as big science, data-driven science, networked science, open science, Digital Humanities, science 2.0, e-Science, e-Social Science, and e-Research have also been used by researchers examining knowledge production processes in the digital age (Karasti et al., 2016). These works fall out of the scope of this report. [ff]

[a] with the exception of SCOSS, the entities named are all US based. It might be helpful to add some examples from other regions, such as Amelica from Latin America and perhaps also TCC Africa?

[b] Also,, the first link from Ford is reporting on research funded not just by Ford - so perhaps mention more in general research into this has been funded by xxx?

[c] thanks, Bianca -- that's a great shout. We'll be sure to amend.

[d] Perhaps elaborate a bit on the expected implications?

(making this more concrete here might make it (even :-) more interesting for people to read the full report)

[e] insufficiently systematic? (as there is a systematic element in the definition)

[f] I feel this, as a concrete goal of the theoretical exploration, would also fit well in Background above (also see my comment there on being concrete on expected implications)

[g] Standardized in what way?

[h] In general, I feel it would be good to be explicit about the extent to which a proposed definition is meant to be general, or specific to IOI - i.e. shaped by the aim of helping to further IOIs goals.

[i] Add a short paragraph on methodology used in compiling this collection of literature?

[j]as well on how it was processed (coding concepts, etc)

[k]see also my comment above on the scope of the intended definition (general or IOI-specific): here, too, I feel it's important to reflect on the extent to which IOIs specific goals will shape these receeommendations (which is a good thing!, but may also limit their generalizability, so that would be good to acknowledge.

[l]Why only mention social sciences here?

[m]I feel that this section is missing a reference to the original report that gave rise to SCOSS in the first place: https://repository.jisc.ac.uk/6269/10/final-KE-Report-V5.1-20JAN2016.pdf. In there, the authors define infrastructure as 'Those services that are invisible to the end user but which contribute, directly
or indirectly, to the successful implementation of OA workflows.' (page 28)

[n]Thank you for flagging this! We'll work to incorporate this into the discussion below.

[o]add a sentence justifying that this is indeed best captured by 'information infrastructure' among the terms above?

[p]Any specific classification that is used here?

[q]I've yet to see an adequate treatment of the variable visibility of infrastructure. The assumption behind Star & Ruhleder's rule is that of an already established, working infrastructure (which can therefore become transparent to end-users); the critiques of this rule mostly come from cases of never-operational infrastructure, often where the "systems and practices operate in variance with their purported objective" (Larkin, 2013, 334). For many of the examples Larkin points to, the intention behind the states that built public works was to signal to an imagined future horizon (we will be modern), not the purported function (water deliver, efficient transportation, etc.). If an infrastructure was never intended to support/enable the explicit function, is it really an infrastructure (or, rewriting Lea & Pholeros [2010] essay title, When is an infrastructure not an infrastructure?)? Perhaps we could compare infrastructures by the ratio of their functionality to visibility: the higher the ratio, the more transparent it becomes, allowing the focus to be on what the supported function affords. The variable visibility of an infrastructure is also tied to the temporality of that infrastructure's life cycle. Is it new or emerging, mostly a promise of an imagined future (the potential of solving specific problems, no longer needing to attend to them)? Is it no longer fit for purpose, compatible with unintended uses or extensions, blocking the way for other infrastructures? Or was it never meant to be a functional system, but to signal institutional buy in for, say, an open science future? My point: Invisibility should be seen as an *aspiration* of a functioning infrastructure. To the extend it is visible, it is failing to live up to its promise.

[r]Book that might be useful in thinking about these issues: *The Promise of Infrastructure,* edited by Nikhil Anand, Akhil Gupta, and Hannah Appel (DukeUP, 2018). Note that it is mostly an extension of political anthropology, and while they include a chapter by Geof Bowker on knowledge infrastructure, his contribution doesn't really fit with that program.

[s]I think Tim raises some really good points about the 'variable visibility' of infrastructure. I agree with the last point especially: that invisibility is aspirational while a person uses it, as it is partially constitutive of functioning infrastructure. However, complicating the picture a bit (as below) avoids, I think, the problems that come with invisibility.

I hope this isn't seen as pernicious self-promotion, but I wrote a very short essay on why we might consider infrastructure as an activity (rather than as merely a tool). Specifically, I proposed a definition that infrastructure is an activity that involves an agent and her trust in the tools she uses. I draw especially on the work of philosopher Christine Korsgaard, who has an account of when artifacts become artifacts -- when they're not in use by agents, they're simply incomplete objects. I extend this to infrastructure as well.

A benefit of the Korsgaardian approach to artifacts as applied to infrastructure is that it partially explains why our necessary role in the functioning of infrastructure as infrastructure seems to fade into the background (we can pick out the piece of infrastructure as the site of action). But if we conceive of infrastructure as an activity and not just a tool, we are less likely to overlook our own involvement in it.

(I also think this helps with the idea of the so-called "boringness" or "invisibility" of the work people do to develop and maintain infrastructure. All maintainers themselves are engaging in infrastructural activity; what's different is the field of view: what more immediately supports a cataloger's tasks differs from that which supports a researcher's retrieval of a record. In this way, there isn't such a gulf between so-called 'users' and those who work on the stuff.)

Anyway, for what it's worth, I provide a link to this very short piece I wrote in case it's at all helpful in thinking about these issues of agency, activity, and as I go on to talk about, trust:

https://doi.org/10.21428/6ffd8432.ae158f91

[t]Infrastructure does not have agency; people do. I strongly dissent from the idea that infrastructure builders and maintainers aim to be invisible. Rather, they are rendered invisible by privilege, neglect, and erasure.

[u]I'm not sure if this is in reply to what I wrote above. If it is, I think we agree. I don't think infrastructure has agency -- because infrastructure is not an agent (though it necessarily

involves agents, imo).

I don't think people who work on infrastructure aim to be invisible either, and I don't think my or Tim's comments are saying that when we're talking about invisibility/receding when in use. Rather, I took Tim's comments to be describing how the way we take up tools/functionally defined objects makes them ready to hand -- and that readiness to hand is a sign the tool is functioning as a tool: when we're using it to perform some task. And that even if that's not all of what is going on with infrastructure (which is what I would say), that's part of it.

*ETA, 4/23 07:21: If readiness to hand were all that was going on, that kind of description does indeed overlook, as the Korsgaard work I draw on for artifacts puts it, the whole 'causal chain' that led up to using an object to perform a function, so that's expressly one reason why I think the whole idea of infrastructure is more complicated than mere readiness to hand, and concentrating on a site of the action isn't the whole view at all (a virtue of Korsgaard's account of artifacts is that it's alive to this). So here I think we agree too, and I appreciate that from your other comments.

[v]I want to echo Tim and Colleen's points about the aspiration and variable visibility. I also hear your points, Dorothea -- and we're working on a more explicit acknowledgement of the nuance in this draft to capture that. Thank you all for engaging with this.

[w]To be erased and neglected, rather. Those of us who do infrastructure work definitely try not to fade, because we know the damage that erasure and neglect do to us and our work.

[x]Agree with Dorothea. It would be helpful to frame the invisibility as erasure, an active choice to ignore and undervalue this critical work until there's a problem. And erasing this work can often lead to dire consequences, like insufficient investment in the maintenance of critical infrastructure. It is all an active choice.

[y]Thanks, both -- I hear your points, and we'll work to incorporate that language. That's aligned with much of our other work on maintenance and labor, and we'll amend to better reflect that nuance and tie in that work here.

[z]Could we frame this as relating to the (non-)observers, rather than to any intrinsic quality of the work or those who do it? I'd prefer "invisibility" or "neglect" or better yet "erasure" to "boringness" here.

Signed, a librarian whose work is routinely erased and overlooked and who decidedly resents it.

[aa]Or let's be even blunter than "erasure" -- how about "scorn"?

[ab]+1 to invisibility here

[ac]I hear your ask to amend this phrasing, and have taken it up with the team. Much appreciated, both.

[ad]In my view, any summary of STS work on infrastructure needs to note the critiques by Lee and Schmidt's 2018 paper, "A Bridge Too Far? Critical Remarks on the Concept of 'Infrastructure' in Computer-Supported Cooperative Work and Information Systems," https://doi.org/10.1093/oso/9780198733249.003.0006, (Open access version available at https://depts.washington.edu/csclab/wordpress/wp-content/uploads/Lee2018.pdf). This paper provides essential analysis of the ambiguities and inconsistencies inherent in STS work on infrastructures.

[ae]Thank you for this reference! We appreciate your help identifying key resources we may have overlooked. We look forward to incorporating the relevant elements from this in our work.

[af]Argh. Okay, I see where you're getting this, but still, I NEED YOU NOT TO UNCRITICALLY ACCEPT/REPEAT IT.

Invisibility is not intrinsic. People choose not to see.

[ag]I think you are reducing infrastructure down to the people who work on it, which I think is a mistake. I've always thought we needed a labor theory of infrastructure to make explicit what is required to create and maintain infrastructures, but that is approaching this from only one angle. An infrastructure's transparency for end-users is what enables them to focus their attention on their own purposes, not the tools that enable them to pursue those purposes. When I'm writing a comment in a Google Doc, I am focused on composing my words, not the conditions that enable their appearance, for me and others. At another moment, I can reflect on what enabled me to post this comment: the labor involved. At another moment, I can pull back further to consider the political economic arrangements that organized that labor, that determines the trajectory of the tool, etc. For many infrastructure studies scholars, me included, transparency/invisibility for end-users is a crucial part of what distinguishes infrastructures from other types of object or systems. Their great benefit (and also danger) is that they enable inattention, so end-users can focus on something else. For me, an infrastructure is the material embedding and extension of the division of labor.

[ah]Getting back to your point, the question is Who needs to be aware of the inner workings of an infrastructure? The only way an infrastructure can fade into the background for end-users is because of the efforts of those who keep infrastructure in the foreground. Who is responsible for creating the conditions where working infrastructures exist and thrive? This is

the level at which the invisiblization of labor is at stake, and the general undermining and neglect of infrastructure.

[ai]I'm well aware that labor is not the only element of infrastructure; I've run servers, served on standards committees, and so on. I am harping on it because this draft currently frames labor in ways that I consider dangerous to laborers and ultimately to infrastructure itself.

[aj]I hear you, Dorothea -- and your frustration.This is a working draft designed for open comment so we can iterate with the community in a constructive way. We'll take this on as a team, but would ask for that understanding as we incorporate your comments and intent.

[ak]This caught my attention because I am so accustomed to relating connectedness with interoperability, and scaling as expansion to handle load. One of the huge problems with multi-tenant architectures is when the overall design has not accounted for scaling of compute, memory, people. And as I see in the next section, this report relates connectedness to interoperability.

[al]Great flag, Robin! @richard@investinopen.org @s.g.goudarzi@gmail.com please see Robin's point about connectedness, interop, and scale above. (Might be worth clarifying to reduce risk of confusion.)

[am]Did you not review any library/archives/LIS literature on preservation, analog or digital, and its infrastructures? That seems a curious omission.

Signed, a librarian wearily accustomed to the rest of the academy ignoring the LIS literature.

[an]Hi Dorothea. I think you have some valuable feedback which could be even more valuable if it is more constructive in nature, for example, providing the references that you are mentioning in this comment so that they could actually refer to those. I also don't think comments in caps are very constructive and it can be very daunting to be on the receiving end of those. As a fellow reviewer I'm already put off by this, let alone someone who has carefully constructed this text.

[ao]+1 to Esther's comments here. The author comes from LIS and those domains, and we'll be making our resources available that were reviewed as part of this initial analysis.

I hear that you would like us to consider further incorporation of those areas you referenced above. I'll share that with the team for further examination. Thank you!

[ap]I note a marked absence of humans and their labor in the table under this paragraph. I think that's worth explicit mention in this paragraph. That's erasure in action.

[aq]SOME individuals and organizations -- typically the ones using or benefiting from the infrastructure, rather than those who design, build, or maintain it.

[ar]+1

[as]Noted! We'll add that qualifier.

[at]From the point of view of a PI only. A research administrator, research IT manager, or librarian would have a very different view.

[au]Indeed, this explicitly takes the perspective of researchers (not just PIs though).

However, as a librarian I also do consider my work supporting researchers in (aspects of) this workflow.

[av]I've matched the colours to our colour scheme ;-)
If you'd like to go one or two shades darker, here are the Hex values:

Darkest:
#BF0000, #CCCC8F, #53A6A6, #DB843D, #339966, #CCA33D

Middle:
#D45454, #DDDDB4, #8CC3C3, #E7AD7D, #76BB98, #DDC17D

Lightest:
#DF8080, #E6E6C7, #A9D3D3, #EDC29E, #99CCB3, #E6D19E

[aw]What if a commercial solution is being used by an academic institute? Is that still open? Or is this not covered by this definition?

[ax]I'm a bit confused as to whether this should be read as as a conclusion from the lit review, or as a boundary set prior to summarizing the literature?

[ay]Just to note that we expanded on this on a follow-up here: http://dx.doi.org/10.6084/m9.figshare.1520432

[az]Thanks for this update! We look forward to incorporating your more recent work on these topics.

[ba]See also early open-access works by e.g. Clifford Lynch, Raym Crow, Alma Swan, Stevan Harnad. They were often (if I am frank) wrongheaded and ridiculously overidealized, but they had a huge impact on the development of e.g. repository infrastructure.

[bb]+1, see e.g. the wonderful 1995 collection of conversations around Harnad's subversive proposal, edited by ARL's Ann Okerson & James O'Donnell:

Harnad, S. (1995). Scholarly Journals at the Crossroads: A Subversive Proposal for Electronic Publishing (A. S. Okerson & J. J. O'Donnell, Eds.). Association of Research Libraries. https://eprints.soton.ac.uk/362894/

[bc]Thanks, both!

[bd]The work happening in the Communiy-Led Open Infrastructures for Monographs (COPIM) project might also be relevant in this context, see e.g.:

Community-led Open Publication Infrastructures for Monographs (2021) COPIM statement on the corporate acquisition of OA infrastructure. https://doi.org/10.21428/785a6451.123ec90e

[be]I wonder if there is a way to also expand this towards the need of open infrastructures themselves being grounded in open values?

The current version of this investigation seems to assume that open infrastructures 'function' to support groups of actors in embedding their values (which might be a bit too utilitaristic, given that infrastructures themselves are not neutral), but as e.g. the recent case of arXiv partnering with Elsevier's Scopus has shown, we need open infrastructures themselves to be more firmly grounded in Governance that is guided first and foremost by open values to provide a framework that - at least potentially - might help against the ongoing enclosure of scholcomm infrastructure by commercial players.

For more on the political nature of infrastructures, see e.g.

Albornoz, D., Okune, A., & Chan, L. (2020). Can Open Scholarly Practices Redress Epistemic Injustice? In M. P. Eve & J. Gray (Eds.), Reassembling Scholarly Communications: Histories, Infrastructures, and Global Politics of Open Access. The MIT Press. https://doi.org/10.7551/mitpress/11885.001.0001

Adema, J., & Hall, G. (2013). The Political Nature of the Book: On Artists' Books and Radical Open Access. New Formations, 78(78), 138–156. https://doi.org/10.3898/NewF.78.07.2013

Birkinbine, B. J. (2020). Incorporating the Digital Commons. University of Westminster Press. https://doi.org/10.16997/book39

Christen, K. A. (2012). Does Information Really Want to be Free? Indigenous Knowledge Systems and the Question of Openness. International Journal of Communication, 6(0), 24.

[bf]+1

[bg]I feel this section could be exploring somwhat more deeply the various aspects of what the 'open' in open scholarly infrastructure means. It seems to me that there is a lot of unexplored terrain between, on one hand, defining open scholarly infra as 'non-commercial owned or operated' (I'm also still not sure how this is grounded in the lit review) and on the other hand, quoting definitions on open scholarly infra as supporting open scholarly practices.

I think what might help here is a deeper discussion on various aspects of openness that are at play (and how they interrelate):-
- the practices enabled/supported by open scholarly infrastructure
- more intrinsic openness aspects of infra (e.g. governance, sustainability, open source).

Litmus test questions here could be:
- Can open scholarly infra support non-open scholarly practices?
- Can open scholarly practices be supported by non-open scholarly infrastructure?

[bh]NB with apologies for the self-referencing - we explored some of these aspects in an interactive exercise here: https://tinyurl.com/workflow-choices, exploring both how the selection of criteria influences what is considered as 'open infra, and also the variability in what openness criteria people/groups consider as important when considering tools/platforms

[bi]The concept of "free" is hopefully something we have moved beyond. I realize this was written in 2007 but portraying open infrastructure as free has undermined the resourcing of the infrastructure in many cases. Having said that, the ways in which people can contribute as the communities supporting open source have a wide array of needs.

[bj]Would suggest to adapt this to the digital realm - although I'm sure there will be more fitting examples, one that comes to mind is video streaming platforms, where we have not only the platform (take the ever-ubiquitous Zoom, or open alternatives such as Jitsi et al., or any other of the variety of 'solutions' that have risen to unprecedented use over these last two years) emerging as critical infrastructure, but also the connected role that each user's dependency on sufficiently-performant access via gateways to the internet plays - and how a drop or breakdown in any one of these nodes in the digital network chain makes the fragility of digital infrastructures visible.

[bk]perhaps a bridge here is also in considering how infrastructure not only supports/facilitates, but also *shapes* knowledge practices?

[bl]Defining things in terms of function is often problematic... the antidote is often to think about *relationality*. I think your "Bottom Line" here is already pointing in this direction (as is the 'socio-technical system' notion that follows.

It doesn't seem too much of a stretch to re-case this first "functional" takeaway by thinking of infrastructure as the stable -- or perhaps actively "stabliized" -- system of relationships that allow the goals of scholcomm (or whatever we're talking about) to be pursued in ways that don't make us start from scratch every time.

So we have an extant, arguably decadent system of relations that make print/subscription scholcomm possible -- and indeed taken for granted by many. And we have a new, fledgling, contested system of relations that we hope will make OA/community-owned scholcomm possible, at scale, over time.

[bm]Apologies... I see most of this has been covered in the next section!

[bn]No apologies needed! It's a great point!

[bo]Also its designers, builders, and maintainers, please. Do not compound the erasure of these people and their labor that I noted several times above.

[bp]Thanks, Dorothea. Appreciate the language suggestion.

[bq]I was looking for any mention of community and the importance of community building, stewardship, etc. In particular, I wanted to see articulation of community as described by Peter Block's "Community the structure of belonging" where working in community redefines the relationships of members and how the work is accomplished. People with various expertise, come together on a level playing field where each person has investment in the success of their shared interest. I think this section speaks to parts of this.

[br]Seconding this! Community building could well be seen as part of the larger aspect of hidden labour that much of open infrastructure relies on. If infrastructure is seen as a socio-technical system (as the title suggests), I would be interested in learning more about the actual social aspects, i.e. hidden labour, people that make things run (be it the work required to keep servers running, software updated, repositories that need managing, or the hidden labour that scholars provide to keep scholarly publishing afloat), these aspects still appear to be missing in this first draft (this also links back to Dorothea's important point(s) raised re: the erasure of labour).

[bs]One starting point might be Adema and Moore (2021) who explore how users and the labour they perform might be understood as 'infrastructure', and e.g., with Anna Tsing, write: "Within academic publishing, volunteer labour provided by scholars (when perceived as something that is part of an academic's workload), forms the publicly-funded human infrastructure the profits in academic publishing are based upon – and the nonscalable elements Tsing refers to, which are extracted for profit in supply chain capitalism."

Adema, J. & Moore, S. A., (2021) "Scaling Small; Or How to Envision New Relationalities for Knowledge Production", Westminster Papers in Communication and Culture 16(1), p.27-45. doi: https://doi.org/10.16997/wpcc.918

[bt]laborers, communities, and organizations, if you please

[bu]Amended!

[bv]riven or driven?

[bw]oops! great catch!

[bx]AND LABOR, please.

[by]added!

[bz]I wonder if this could be expanded to include an understanding of the role that organisational and cultural practices themselves play as 'nonscalable human infrastructure', see e.g. Adema and Moore (2021) for more on this aspect.

[ca]Also just to note that 'successful' for me always immediately raises the question of 'successful for whom', as there's hardly a universal definition of what success means in this context

[cb]users, designers, builders, and maintainers

[cc]second this

[cd]added!

[ce]or themselves act as infrastructural elements (e.g. scholars' provision of free labour to facilitate peer review, upon which corporate business models are built [see Tsing, in Adema&Moore 2021]; or the free labour provided by open-source communities)

[cf]Crucial piece for understanding how many pieces of scholarly communication infrastructure emerge from, but eventually work at cross-purposes, with researchers and their institutions: "The Long-Now of Technology Infrastructure," by David Ribes and Thomas Finholt, https//:doi.org/10.17705/1jais.00199

[cg]and vice versa?

[ch]Self-cite: "How to Scuttle a Scholarly Communication Initiative", https://jlsc-pub.org/articles/abstract/10.7710/2162-3309.1075/ If the satire itself isn't helpful, the cited literature certainly will be.

[ci]See also Quinn Dombrowski on the crash-and-burn of Project Bamboo.

[cj]thanks, Dorothea!
[ck]ongoing resourcing, labor, monitoring, development, and maintenance
[cl]Second this change!
[cm]+1
[cn]amended! thanks, all!
[co]"resourced and actively maintained" is usefully more specific, I think
[cp]Agreed
[cq]+1
[cr]amended! thanks again, all.
[cs]"erased" or "ignored," please
[ct]+1 Seconding this, would suggest "usually-neglected" as an alternative notion
[cu]thanks, both!
[cv]Erasing people and their labor, again. Please don't. Rephrase to something more like "investigating the people, labor, and processes of infrastructure"
[cw]Second that!
[cx]amended!
[cy]AND PEOPLE, AND LABOR
[cz]updated!
[da]Which people? Again, this shouldn't be reduced to "users" as it often is in this piece.
[db]workers, systems, and processes
[dc]+1
[dd]updated!
[de]resources, workers, relations, and processes
[df]+1
[dg]thank you!
[dh]its erasure
[di]incorporated!
[dj]open infrastructure, its dynamic qualities, and the people who design, build, maintain, and support those qualities
[dk]+1
[dl]add a reflection on *open* standards and their implication for interoperability and preventing lock-in?
[dm]In line with another comment made on this sentence, I would caution against preferential attention on large-scale, and instead at least also pay attention to initiatives that serve the needs of smaller/niche community/domain/use cases. Such diversity can be also a useful antidote to de facto monopolization/oligopolization as an inherent risk of a focus on scaling large. Standards could be a way to bridge those two approaches, enabling interoperabiluty while maintaining diversity.
[dn]PS I do notice the importance of diversity and uniqueness of infrastructures is addressed more deeply in the next section. The tension with this section might still be important to explore further though.
[do]I understand the notion of scalability as being relevant in relation to a perspective that focuses on technology (re: standards & interoperability etc.). To also account for the social in the underlying notion of 'socio-technical infrastructures", I would suggest to not solely focus on scalability in the traditional sense of 'scaling up'. As Anna Tsing notes, scalability also bears negative effects that need to be considered, such as homogenization corresponding loss of diversity. Tsing introduces a theory of nonscalability, to highlight the potential that small-scale experimental infrastructures hold. See Adema&Moore's (2021) notion of Scaling Small which builds on Tsing's theory of nonscalability.
[dp]+1
[dq]The Large Technological Systems wing of infrastructure studies provides some useful concepts for evaluating the temporality of infrastructures, such as path dependency and gateways. For an overview: Christian Sandvig, "The Internet as Infrastructure," https://doi.org/10.1093/oxfordhb/9780199589074.013.0005; Thomas Hughes, "The Evolution of Large Technical Systems," ; and Tineke Egyedi, "Infrastructure Flexibility Created by

Standardized Gateways: The Cases of XML and the ISO
Container," https://doi.org/10.1007/s12130-001-1015-4.

[dr]The Egyedi piece is especially useful in thinking not just about the growth of an infrastructure, but its variable flexibility over time: standards-based gateways are usually meant to increase the modularity and flexibility of an infrastructure, but the degree of flexibility can vary over time.

[ds]and maintainer

[dt]and maintainer

[du]+1

[dv]cultural, political, economic, LABOR, and ethical

[dw]added!

[dx]Also particular groups being abused to provide it. See e.g. the large literature on abusive MTurk practices by researchers, and of course the constant and consistent maltreatment and erasure of librarians and archivists by researchers, research funders, and research administrators.

[dy]Oh, and abuse of student labor too -- "hope labor" is a useful search term here (Miriam Posner has written about it, but she isn't the first or the only).

[dz]and their designers, builders, maintainers, and supporters

I know I keep harping on this, but it's IMPORTANT. Infrastructure is soylent. It's made of PEOPLE.

[ea]incorporated!

[eb]Oh no. No, walk away from this word, please. "Inclusive" is okay here. "Neutral" is very, very, very not. Desmond Tutu and Elie Wiesel have trenchant observations on neutrality being a mask for taking the side of oppressors.

[ec]Just to second Dorothea's important point: see also W.E.B. Du Bois and Angela Davis. Remi Joseph-Salisbury & Laura Connelly's _Anti-Racist Scholar Activism_ has some discussion of this (pp.12-13 and elsewhere: https://manchesteruniversitypress.co.uk/9781526157966/) - this is just what I have to hand right now, but there's a considerable body of literature on this.

[ed]I'm also noticing that this Q. doesn't seem to fit with your important point above that 'infrastructure is not neutral'. If that's true (as I think it is) , then it doesn't make sense to ask how IOI could determine if a given OI was _not_ neutral.

[ee]Definitive +1 re: moving away from the use of 'neutrality' here

[ef]I hear you. Thank you all for flagging. We'll amend.

[eg]I would add something like "extracted" here too

[eh]Great call. Thank you!

[ei]knowledge, labor, and socio-economic inequities

[ej]added!

[ek]I don't see what this has to do with it. Well-served communities can still abuse labor, oppress, exclude, etc. That's not okay.

If you mean "how do we ensure all communities are equitably treated in the development and maintenance of open infrastructures?" then say so -- absolutely a legitimate question -- but this is not that.

[el]I like that phrasing, Dorothea -- will incorporate, and thank you for surfacing.

[em]You didn't review it. As noted above, this piece completely ignored LIS. I'll make a start toward work it should consider at the end.

[en]Hi there - I don't find this comment constructive, nor respectful of the author and team's work. I hear your frustration, but please look to build on the ideas here, not critique the author.

[eo]I would add Community Building and Stewardship

[ep](4) labor infrastructure -- Ensmenger, Downey, Hicks, etc.

[eq]adding!

[er]would suggest to also expand towards more Humanities-based approaches, including the earlier-mentioned work of anthropologist Anna Tsing on nonscalability, also via Adema & Moore (2021) https://doi.org/10.16997/wpcc.918

In case these aren't already on your radar, the following might also be useful to consider:

- Fitzpatrick, Kathleen. 2011. Planned Obsolescence: Publishing, Technology, and the Future of the Academy. New York: New York University Press. https://mcpress.media-commons.org/plannedobsolescence/

Fitzpatrick, Kathleen. 2007. 'CommentPress: New (Social) Structures for New (Networked) Texts'. The Journal of Electronic Publishing 10 (3). https://doi.org/10.3998/3336451.0010.305

- Chen, George (Zhiwen), Tasneem Mewa, Denisse Albornoz, and Maggie Huang. 2018. 'Geopolitical Inequalities Behind "Open" Infrastructures for Academic Knowledge Production'. In The Geopolitics of Open, edited by George (Zhiwen) Chen, Ángel Octavio Álvarez Solís, Gabriela Méndez Cota, Maggie Huang, Denisse Albornoz, Tasneem Mewa, and Culture Machine, 6–15. Coventry: Post Office Press, Rope Press, and Culture Machine. https://hcommons.org/deposits/item/hc:19819/

- Ross-Hellauer, Tony. 2016. 'Infrastructure Is Invisible / Infrastructure Is Law'. OpenAIRE Blog (blog). 5 June 2016. https://www.openaire.eu/blogs/infrastructure-is-invisible-infrastructure-is-law-1

- Eve, Martin Paul, and Jonathan Gray, eds. 2020. Reassembling Scholarly Communications: Histories, Infrastructures, and Global Politics of Open Access. Cambridge, Massachusetts: The MIT Press.

- Dunbar-Hester, Christina. 2019. Hacking Diversity: The Politics of Inclusion in Open Technology Cultures. Princeton University Press.

- 'Research Infrastructures in the Humanities : European Science Foundation'. 2011. http://tiny.cc/3h6ruz

- Pooley, Jefferson. 2017. 'Scholarly Communications Shouldn't Just Be Open, but Non-Profit Too'. Impact of Social Sciences (blog). 15 August 2017. https://blogs.lse.ac.uk/impactofsocialsciences/2017/08/15/scholarly-communications-shou

[es]COPIM's recently-published report on community governance of open infrastructures might be of interest here:

Hart, P., Adema, J., and COPIM. 2022. Towards Better Practices for the Community Governance of Open Infrastructures. Community-Led Open Publication Infrastructures for Monographs (COPIM). https://doi.org/10.21428/785a6451.34150ea2

[et]Oof. Maybe take a look at the history of "research data lifecycles," perhaps via https://researchportal.bath.ac.uk/en/publications/review-of-data-management-lifecycle-models which is quite good. Project Bamboo's crash-and-burn is also material here. (I have relevant rants on the OAIS model too, but I'll spare you.)

"Taxonomies... of functions" frequently end up gappy, one-size-fits-absolutely-no-one exercises in total frustration.

I think a maturity model (or several) is likely to be a much more useful and broadly-applicable frame than "taxonomy" here. See e.g. the NDSA Levels of Preservation for the kind of thing I mean.

[eu]Appreciate flagging that resource and language. We'll review and work to incorporate.

[ev]I also feel the dichotomy here is more a 'working assumption' than a conclusion from the literature overview - and as such probably deserves a stronger rationalization -why is this aspect (among many) chosen as defining open infra?

[ew]Whose? Given the consistent erasure of design, build, maintenance, and support labor and those who perform it in this piece and its antecedents, I think specificity is well warranted.

[ex](I will add that as a librarian, institutional-repository manager, research-data manager/consultant/educator, information rescuer, and open-access advocate -- this piece does not speak for me and my infrastructure-related experiences AT ALL. I don't think that's something I caused or bear responsibility for. I think that's a major faultline in this piece, which privileges the point of view of researchers and excludes every other point of view and those who hold it.)

[ey]I hear your point asking for more specificity here -- and appreciate you sharing your feedback. We'll review and work to update the language to reflect that.

[ez]I'm not convinced by this distinction. The traditional commercial fee/print/subs/market based infrastructure values and privileges a set of social/cultural practices and, er, values too. So the task is to identify how and why the ones that OI privileges are different.

An obvious one is about market performance as a proxy for scholarly value... a tangled knot of value propositions that most commercial scholarly publishers find themselves beholden to, or at least suspended in. It's not just that profitability is a goal, it's the idea that profitability = success.

[fa]+1

[fb]As promised, some LIS (and, as it happens, digital humanities -- DH is better at thinking through maintenance and care issues than the sciences generally are) literature that should inform this piece.

Shirazi 2014. https://roxanneshirazi.com/2014/07/15/reproducing-the-academy-librarians-and-the-question-of-service-in-the-digital-humanities/

Caswell 2016. https://escholarship.org/uc/item/7bn4v1fk

Au 2020 (not scholarly, but important), https://counting.substack.com/p/data-cleaning-is-analysis-not-grunt?s=r

Muñoz and Guiliano 2014, https://trevormunoz.com/archive/posts/2014-07-14-making-digital-humanities-work/

Huculak and Goddard 2016. https://acrl.ala.org/dh/2016/07/29/a-case-for-care-and-repair/

Posner (lots of Posner, actually, but start with) https://miriamposner.com/blog/here-and-there-creating-dh-community/

A Student Collaborators Bill of Rights https://humtech.ucla.edu/news/a-student-collaborators-bill-of-rights/ (and see also Spencer Keralis, https://digitalhumanities.rice.edu/2016/03/03/talk-by-spencer-keralis-on-disrupting-student-labor-in-the-digital-humanities-classroom/)

Thomer et al. 2022. https://arxiv.org/abs/2202.04560

There's lots more, of course, but this is a start.

[fc]thank you! appreciate you sharing these here for us to learn from and review.

[fd]No. Again, this is NOT A QUALITY OF THE WORK OR THE SYSTEMS. It is a quality of who does and doesn't choose to notice them!

[fe]A reminder that this is pulling from the way this has been described in the literature, and I agree with your point (but did not read this footnote the same way). We'll work to clarify.

[ff]Why? And where's the constellation of digital curation / data curation / data stewardship? Again, lots of LIS literature under those headings.