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Governance by information infrastructures: Origins and evolution of the concept

by Robin Williams, Antti Silvast,
and Francesca Musiani

Abstract

The term “infrastructure” has evolved to span a wide range of disciplines, reflecting its diverse applications and conceptualizations. This paper argues that *information infrastructures* (II) represent a distinct and increasingly significant socio-material form, crucial for understanding governance by infrastructure. We examine the origins and evolution of II, emphasizing the socio-material differences between II and other technological forms such as systems and online platforms. We highlight particularities of II innovation and implementation process and consider their implications for the politics of technology and governance by infrastructures. Our analysis is grounded on examination of several II in our increasingly digitised information societies, spanning the Internet, social security, platforms, financial infrastructures, energy systems and infrastructures, and health information systems.

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Introduction

Usage of the term *infrastructure* has proliferated across the social sciences and humanities. The emergence of the Internet and proliferation of computer networks prompted a hugely influential development of research into Information Infrastructures (II) (Star and Ruhleder, 1996; Hanseth, *et al.*, 1996) encompassing science and technology studies (STS) and related interdisciplinary social science fields such as information systems and computer supported co-operative work (Monteiro, *et al.*, 2013; Edwards, *et al.*, 2024). Infrastructure has been linked with an increasing variety of other qualifiers as well as II, including not only cyberinfrastructure (Jackson, *et al.*, 2007), knowledge infrastructure (Edwards, 2010) but also Data Infrastructure (Sørensen and Kocksch, 2021) and digital infrastructure (Hanseth and Modol, 2021), to name just few. The term now spans a wide range of disciplines, including anthropology, urban studies,

participatory design, digital humanities, sociology as well as STS. This conceptual diversity is valuable, reflecting the dynamism and productivity of the scholarly discourse. However, it also raises legitimate questions about conceptual differences. This increasing terminological popularity, described by some as an ‘infrastructural turn’, raises questions about whether the established term “infrastructure” has retained its analytical utility, if it can be so widely and apparently interchangeably applied (Lee and Schmidt, 2018; Hesmondhalgh, 2021; Edwards, *et al.*, 2024).

Furthermore, and crossing the above-mentioned disciplines, the term has now found its way into literatures that address the definition and the distribution of power in socio-technical systems, such as governance studies and, more specifically, Internet governance studies, which have traditionally been more reliant on political science and law (see *e.g.*, Epstein, *et al.*, 2016).

Some have used the concept of infrastructure interchangeably with more conventional terminologies such as networks and systems (Van der Vleuten, 2004). Other alternative — though certainly not interchangeable — concepts currently range from platforms (Plantin, *et al.*, 2018) to assemblages (Hanseth and Modol, 2021), a social theory of complexity, which stresses the interplay of stabilizing and destabilizing processes in compositions of heterogeneous components and relationships.

In this paper, we develop the argument that the concept of II characterises a distinct socio-material form that is increasingly prevalent in our emerging digital and information society and that can be contrasted to established terminologies of systems and platforms. Hanseth, *et al.* (1996) emphasised the heterogeneous and changing settings for II development that frustrated attempts at centralised, top-down control pursued in technology systems. IIs in contrast refer to evolving ecosystems of interconnected elements, stretching across space and time, and open to many types of users with various objectives (Monteiro, *et al.*, 2013). This analytical move has promoted a growth of empirical research and also theoretical innovation — creating new ways of conceptualising infrastructure development such as infrastructuring (Pipek and Wulf, 2009) and infrastructuration (Edwards, 2019).

Our overarching objective is to demonstrate how these critical differences manifest when examining the topic of governance by infrastructure. While many kinds of large technology systems and assemblages exist and share similarities in terms of being distributed and massive in scale, the infrastructure concept and II in particular offers a double analytical benefit, first in highlighting the processes through which IIs are created, maintained, and used and how this dispersed process is governed and second in terms of understanding power, politics, and therefore governance by IIs.

We address these aims by exploring the origins and evolution of the concept of infrastructure, with a particular focus on the research tradition of II and examining how II offers insights into governance by infrastructure. To ground our perspective, we draw insights from the contributions to the special issues of *First Monday* on “governance by infrastructure”, thus vindicating our conceptual approach and the distinctive features of II as a form of governance.

The politics of technological systems

The field of technology studies emerged through debates in the 1980s that were inspired by overarching concerns about the ‘impacts’ of technology. Various perspectives emerged, united by their critique of technological determinism: the idea that technology develops independently from social life and advantages particular social arrangements (Bijker, 2009). It is important to note how pervasive technological determinism was — exemplified by Bell’s (1973) widely circulated prediction that the widespread adoption of information technology would impose a generalised transformatory logic, heralding the advent of a post-industrial information society. In contrast, embryonic 1970s and 1980s efforts in the science, technology, and society movement focused on the negative as well as positive impacts as well as the risks of

technologies (Sismondo, 2010).

Some critical studies began to question the form of technology design and the trajectory of its development. Thus MacKenzie and Wajcman's (1985) influential social shaping of technology perspective, posed "a prior and perhaps more important question": "what has shaped the technology that is having effects. What has caused ... the technological changes whose 'impact' we are experiencing." [1] Their model of technology politics was aligned with the influential work by Winner (1980) — claiming that the politics of technology manifests because the designers of technology either purposefully or tacitly require, or at least favour, certain kinds of social order. This was exemplified by an account of bridge design by Robert Moses in the United States, which was allegedly built with low headroom to restrict access by public buses rather than automobile users, thereby limiting access by poorer and ethnic minority populations to public beaches (Woolgar and Cooper, 1999).

This essentialist conception of the politics of technology (Sørensen and Williams, 2002) involved two presumptions:

- that the values surrounding the design and development of technology become embodied in technology artefacts and
- that these are reproduced when they are implemented and eventually used.

Technology was thus seen as a vehicle for delivering social and organisational transformation. This conception became very influential in the 1980s 'technology debate', provoked by the widespread industrial uptake of microelectronics which labor process theory (Braverman, 1974) and concepts of informatisation of work (Zuboff, 1988), for example, saw as entailing technology-driven restructuring of work.

Other early technology studies contributions included work on large technological systems (LTS) — such as electricity networks (Hughes, 1983). A general definition of a system in the LTS tradition is that it "is composed of interconnected parts or components ... linked by a network or structure" [2]. LTS research conceptualizes systems as entities encompassing controllable components — typically centrally managed — while excluding elements beyond control, which are considered part of the system's environment. Hughes [3] and many others (see review in Silvast, *et al.*, 2013) examined electric power supply as a prime example of a large system, comprising "physical artifacts, such as turbogenerators, transformers, and transmission lines in electric light and power systems", while also including "organizations, like manufacturing firms, utility companies, and investment banks", "scientific components, such as books, articles, and university teaching and research programs", "legislative artifacts, like regulatory laws", and "natural resources, such as coal mines".

Through the definition is broad, and the LTS research tradition is characterized by internal diversity and has resisted rigid boundary definitions (Van der Vleuten, 2004), we argue that the foundations of LTS seem to tacitly offer a familiar 'Winnerian' account of the politics of technology. This happens because over time, LTS become increasingly unmalleable. Mature large systems tend to accrue momentum to use the LTS concepts and become increasingly fixed — or path-dependent to use an economic historians' term. This happens, for instance, because the standards, organisations, laws, and physical components of large systems start to interlock and changing any one component is difficult without changing all of them. Various actors may also become invested in a shared paradigm entrenched in the education of engineers and the routines of technology developers and adopters alike.

In governance terms (Coutard, 1999; see Silvast and Virtanen, this issue), LTS are characterized by hierarchical organization and strong influence by national regulatory authorities. Conventional LTS were generally assumed to enjoy public acceptance, and national governments and LTS companies often collaborate to create and expand these kinds of systems over geographical space. Some identified a convergence of values and approaches around the stabilised creation and operation of these LTS involving political consensus and shared perspectives on centralised control and hierarchical management (Collingridge, 1992).

Of course, this narrative of stable, centralized governance has not accurately reflected most LTS for a long time. As such, these systems and the values they embed were never stably fixed. Instead, a shift away from the traditional model of centralized and politically steered infrastructure towards more diverse and market-oriented approaches to infrastructure governance has been ongoing for several decades. This transition, led by economists and governments as early as the 1960s and intensifying in the 1980s and 1990s, is exemplified in attempts to deregulate and partially privatize infrastructure services and open aspects of them to economic competition (Graham and Marvin, 2001).

Nevertheless, such an approach to technology politics had influence much beyond large systems of energy provision. Scholars looking to understand the character and implications of emerging information and communication technology networks in the 1990s drew metaphors from physical infrastructure — understanding the Internet as if it were railways or superhighways, for instance (*e.g.*, Kubicek, *et al.*, 1997).

This has led scholars to emphasize the fixedness of infrastructure and their pervasive reach. Outside of Information Systems research and STS, it encouraged others — such as the famous theorist of sources of power, Mann (2008) — to argue that power is infrastructural. Infrastructural power is the power of the state to permeate the civil society across its territory, contrasted to despotic power, which is exercised without consulting civil society. Infrastructural power is one source of social power alongside ideological power (over meaning systems), economic power (over resources), military power (over violence), and political power (over social life). In practice, infrastructural power has several dimensions. These include concrete resources that are potentially accessible to infrastructural power, such as energy, natural resources, and physical networks. The weight of this power depends on the resources that can actually be deployed. Variations of power include subnational power differences in terms for example of distinct infrastructural power in different cities and regions. Nevertheless, the initial assumption is very similar to Winner (1980) in that infrastructure is a means of radiating power from the state outward [4].

Alongside this, some early technology studies scholars began to unpick the form of technology. In particular, Fleck (1988) contrasted the received model of the creation of dedicated ‘technological systems’ by a single or centrally coordinated supplier with an emerging pattern by which firms secured their information systems requirements by selecting and knitting together a range of off-the-shelf and customised components into a looser configurational technology solution to match their requirements. This exploration into differences between specific technologies — their technological forms and development processes — fed in to the conceptualisation of information infrastructure. Monteiro and Hanseth’s (1996) key observation about the successful growth of the Internet as an emerging ‘network of networks’, achieving flexibility in its widespread deployment through its distinctive system development and standardisation strategies (modular design; layered architecture; multiple development and diffusion cycles). They highlighted that the evolving heterogeneity of IIs is far-removed from the stabilisation implied by the systems metaphor. IIs are “always an unfinished work in progress” [5] and ‘constantly evolving’ [6].

Over the years, several notions have been coined to emphasize the embeddedness of infrastructures in both time and space, while highlighting their evolutionary and systemic qualities, two of which are of particular interest to highlight here. On one hand, Barry’s (2006) notion of technological zones (and more specifically, of infrastructural zones) helps to make sense of spaces within which differences between technical practices, procedures and forms are reduced and common standards are established. The notion alerts to the “need for analysis of the historical construction of particular political and economic spaces, and the specificities of the materials, practices and locations which they transform, connect, exclude and silence” and emphasizes that “the formation of technological zones has become critical to the constitution of a distinction between global/Western political and economic forms and their non-Western others” [7].

On the other hand, recent work on the concept of *infrastructuring* (Pipek and Wulff, 2009; Blok, *et al.*, 2016; Karasti and Blomberg, 2018) helps to make sense, theoretically and methodologically, of infrastructures as processes, practices, and settings that are both expansive and open-ended, even as our starting point as researchers is made of “spatially, temporally and organizationally circumscribed” case study infrastructures. The shift of attention from infrastructures to infrastructuring allows investigators to

account for how a “field is constructed by the engagement of the researcher with the phenomenon of study, and in the process the object of inquiry delineated, if only for the moment” [8].

Alongside these contributions from the STS tradition and related information systems and collaborative design fields, it should be noted that understanding and analyzing infrastructures and their relation to governance is a multi-disciplinary endeavor, calling for a cross-fertilization of approaches. A foremost example is architect/urbanist Keller Easterling’s (2014) theorization of infrastructure as “extrastatecraft”: according to her, a number of important changes in modern world politics and governance are embedded in the spatial layout of infrastructure, architecture, and urban design. Multiple forces and actors influence and contribute to shaping this infrastructure — from state to non-state, from market-based to civil society-led.

This multidisciplinary is evident in the different perspectives on infrastructure advanced within this special issue. Topics already substantially developed other fields — for example, issues of representation and meaning in media and Internet research (Hesmondhalgh, 2021) — are cast in a new light when taking an infrastructural point of view. For example, focusing on policy discourse, Bennani-Taylor (2024) demonstrated how II combine systemic characteristics with discourse and rhetoric as well as materiality. Such an infrastructure perspective is central to improve understanding of AI: “The concept of discursive infrastructuring offers an opportunity to shed light on the discursive tools through which AI policy documents attempt to stabilise AI as a situated socio-technical assemblage” (Bennani-Taylor, 2024). Similarly, Dal Molin (2024) examined large language models (LLMs) and considered the concept of “language as infrastructure”. She developed new approaches to the governance of LLMs and their social biases, including participatory design and dataset curation, also inherent to II programmes.

Governance of infrastructure

Fleck’s (1988) analysis of configurational technology, in contrast to “systems” technology, opened up enquiry into the very different distributions of agency afforded by different technological forms, with their distinctive innovation processes and innovation governance challenges. Fleck (1988) highlighted the role of users in selecting and implementing components of configurational technology solutions in contrast to the development of dedicated technology systems by a single supplier (or a main contractor plus subcontractor as we see, for example, in the case of airliners).

In a forthcoming work (Silvast, *et al.*, under review) we have addressed the difference between infrastructures and systems (see also Silvast and Virtanen, this issue). We reviewed the diverse body of work on infrastructures and systems in recent decades, drawing especially on Edwards (2010) who in considering the creation and maintenance of large systems (Edwards, *et al.*, 2007) opened an important discussion on competing digital technology forms. In doing so, he distinguished between systems, networks, and internetworks, or as it later became summarised, systems and infrastructures (Edwards, 2010). In the case of systems, the focus is on sociotechnical configurations that are more or less bounded and closed, operating according to established parameters despite containing diverse components and sub-systems. Their systemic operation is typically reinforced by institutional frameworks and legislation, such as those stipulating electricity system operation, licenses, or system responsibilities. We emphasize that such systemicity is a particular kind of sociotechnical achievement particularly by specialized systems builders that have pursued more or less explicit strategies for standardization and scaling based upon a systems perspective (Hughes, 1983).

In stereotypical systems technologies, the lower levels may be developed and operate more or less robustly and as black-boxed solutions. Systems are thus amenable to centralised control, in contrast to IIs which are constituted by coordination of heterogeneous and changing elements (Monteiro, *et al.*, 2013, Lee and Schmidt, 2018). Echoing the contrast between configurational and systems technology solutions, II analysts likewise emphasise the active roles of a range of intermediate and final users as well as developers in

creating and maintaining IIs. II in particular often arise from the integration of diverse discrete information systems. They are assembled and run through the combined efforts of multiple dispersed actors, operating in differing locales and at different scales, from local to regional, national, and even international. Indeed, for IIs, design and implementation always unfold in parallel. In contrast with the vision of top-down creation of centrally controlled monolithic systems, infrastructures are highly distributed phenomena, erected often over an extended period by linking together multiple diverse components. This distribution of agency amongst heterogeneous actors with diverse perspectives presents particular governance problems for II development and evolution. In the absence of a single player with the authority and knowledge required to direct innovation centrally, innovation governance is necessarily distributed (Shen, 2019) — shared amongst diverse players with partial perspectives — and also tentative (Kuhlman, *et al.*, 2019), evolving as understanding grows. II governance is achieved through coordination rather than centralised control (Monteiro, *et al.*, 2013; Lee and Schmidt, 2018). Thus Elizondo (this issue) shows how the governance of Health II development involves the orchestration of change amongst multiple actors with differing commitments and roles.

Many emerging digital networks have features of IIs. However, with the proliferation of social media and the growth of digitisation we find a range of socio-material forms including competing models such as social media platforms which have very different development and scaling strategies and distributions of agency (Plantin, *et al.*, 2018).

Investigations into IIs (and configurational technologies) invite evolutionary research designs where technology development and implementation involve attending to diverse players with more or less diverging immediate and longer-term perspectives and goals. The II development and implementation process is distributed across many settings and occurs on a longer time scale. This may present challenges to conventional research designs based upon short-term, local studies (Hyysalo, *et al.*, 2019).

We further note that differences in socio-material forms may thus be a matter of epistemology as well as ontology. The contrast between IIs and systems between IIs and systems may also in part reflect differences in what the researchers attend to. In accounts of the systemic functioning of platform and systems, the robust operation of the various constituent components is inferred by the researcher who may deploy the language of systemicity to cover up that they are not investigating the operation of lower levels or differences between locales (Edwards, *et al.*, 2024). Indeed researchers can often get away with ignoring other levels and settings where these are *de facto* operating reliably without breakdown. In contrast studies of IIs have emphasised their breakdown (Star and Ruhleder, 1996) as well as the, often overlooked, processes of repair and maintenance to mitigate this.

Pidoux, *et al.* (2024) focused on the Uber platform, which on a closer look, operates rather like a global II: an underpinning of the “gig economy”, allowing information exchange across national borders and hence making the gig economy international. Pidoux, *et al.* illustrated vividly how the governance of infrastructure — the attempt to impose local labour laws to Uber driving in Geneva — met friction. The power of one corporate actor had to be confronted in order to obtain detailed driving data — such as defining the working time of drivers with verification. Various stakeholders from gig workers to data scientists, trade unions, lawyers, and the State all depend on sharing information via an information structure confronting diverse interpretations. This led to power differences that were influenced by information access, which “means tools require maintenance within a sociotechnical and juridical infrastructure that supports multiple social groups to have an egalitarian access to calculative power” (Pidoux, *et al.*, 2024).

Governance by infrastructure

Our improved understanding of these differences in how we develop and implement information systems

also has a significant bearing on the ‘impacts’ of their adoption and use and how we conceptualise these. Early technology studies and business studies perspectives emphasised technology-driven restructuring of work and rationalisation of organisational processes. However detailed ethnographic studies challenged these widespread presumptions. Suchman’s (1983) description of an accounts management office revealed that even ‘routine’ accounting procedures could not be accomplished by following simple formal rules but involved improvisation and collaboration to resolve ambiguities. The improvised character of many organisational activities underpinned the difficulties then coming to the fore in capturing and supporting more complex organisational processes through computers.

If, as Suchman (1983) argued, the effective conduct of organisational processes is a collective achievement of the actors involved, this has implications for how we understand the politics/impacts of IIs. While some highly routinised functions (*e.g.*, book-keeping) can be readily be wholly automated, remaining ‘residual tasks’ are likely to be less amenable to formalisation and automation. Their execution will depend upon the active involvement and engagement of ‘end users’. Nowhere is this more apparent than in the field of health information infrastructures, where the engagement of clinical staff has been seen as key to achieving digital transformation in health care delivery. But if the outcomes of a new wave in the evolution of an II represents a collective achievement that depends in no small part on the active engagement of end users, this conditions the kind of power that central actors are able to achieve and sustain.

Suchman’s study provides a snapshot of office work. It would be unhelpful to take that as the start and end point of enquiry. Tasks that were unmanageable at one time can become tractable and amenable to computerisation, perhaps through the creation of new functionalities or the establishment of standard procedures (Williams, *et al.*, 2004). Conversely standardisation may in turn be undermined by further innovation in technologies and organisational processes.

Podoletz and Currie (2024) developed a dedicated focus on social security and specifically the U.K.-wide automated social security system called Universal Credit. Podoletz and Currie studied Universal Credit directly as an II: a composition made up of a dynamic payment system and personal online accounts of claimants. The specific interest was in how this II embedded a standard of temporality, namely a monthly assessment period, which made time ‘infrastructural,’ imposed on claimants among many other temporal rhythms, such as future work contracts. Once claimants acted upon the infrastructure, temporal effects migrated to their partners and dependents, demonstrating how II could exercise disciplinary power in highly diffuse settings over space. Here the II framework provided crucial insights by opening up for exploration the way in which achievements at particular moments in an evolving II built upon the installed base of existing technologies, procedures, and practices. This state of affairs presented methodological challenges. What may be achievable at a particular moment depends upon longer-term historical processes. Rather than undertaking short-term ethnographies that prevail in much contemporary research, scholars may need to combine studies across multiple contexts of II development and use over extended timeframes (Hyysalo, *et al.*, 2019; Silvast and Virtanen, 2023, 2019).

From governance of to governance in and by infrastructure: The example of Internet governance (studies)

As the previous discussion has shown, perspectives examining infrastructures from a socio-technical standpoint have multiplied over the last decades, and this has included digital and information infrastructures. The bodies of work discussed so far have gradually paved the way for the development of a perspective that allows us to think about power and digital technologies by placing infrastructure at the heart of the reflection. This has been of particular interest for an interdisciplinary field of study that has traditionally primarily relied on political science and on law — the field of Internet governance studies. The contributions of infrastructure studies now allow to understand Internet governance beyond institutional power relations, as a set of socio-technical processes of innovation, digitalization, regulation, mobilization,

co-optation, and circumvention. This section will briefly retrace how, in Internet governance studies, researchers have followed a path that has led them from the analysis of governance of infrastructures, to then move to governance in infrastructure and by infrastructure. Through the practical example and case study of the Internet and its governance, this section shows how a particular — perhaps the quintessential — II has gone through a socio-political and socio-technical set of processes that have first led to elaborate a number of institutions specifically destined to the governance of this infrastructure, then to work towards inscribing some functions of governance in this infrastructure, and third, to co-opt (some of) these inscribed functions for broader political goals.

Since political and economic strategies for the Internet began to be outlined, Internet infrastructure and “critical resources” have been the target of governance strategies and debate, with heated discussions regarding which institution or set of institutions should ‘control the Internet’ (Goldsmith and Wu, 2006). Thus, the governance of Internet infrastructures has long been a sensitive subject for one main reason: the functioning of our “virtual” world involves the allocation and consumption of resources such as Internet addresses, domain names, and even system numbers (Autonomous System Numbers [ASNs], unique identifiers used for routing Internet traffic). These resources, being limited and fundamental to the proper functioning of the Internet, are historically considered “critical Internet resources” and their governance is managed by a set of institutionally complex entities, some of which have been created *ad hoc* to manage a specific part of Internet resources, some of which have needed to re-invent themselves totally or partially in order to stay relevant in the “pervasively digital” age. Much early Internet governance literature has examined these different institutional arrangements needed to enact governance of infrastructure.

However, an increasing number of studies have examined the extent to which the arrangements of technical architecture are intrinsically arrangements of power (DeNardis, 2012). These studies show how infrastructures embed Internet governance functions within them, and are the subject of controversies which relate to the values anchored in each of them. These illustrations of “governance in infrastructure” show how, recurrently, there are inherent links between architectures and infrastructures of Internet and the “making of” its governance and underlying social values. Internet governance infrastructures — its core set of protocols, or the Domain Name System, to name but two – incorporate in several ways public interest concerns, such as privacy, access to knowledge, and freedom of expression, into the design of their technical features (see *e.g.*, Flanagan, *et al.*, 2008).

The design and development processes necessary to keep the Internet operational ultimately contribute to the construction of the digital public sphere and mediate arrangements of power, freedom, and authority within that sphere. Many of these features and processes take place in the backstage — not intentionally hidden, but not necessarily visible to Internet users. Almost none of the “governance in infrastructure” functions are primarily managed by states and their governments, and rarely do these governance functions involve direct manipulation of content, or direct engagement of individuals online.

To take a direct example of this government role, Collier, *et al.* (2024) gathered data on a pivotal example of information blending with marketing through an II: the Meta Ad Library, which is a repository of government advertisements and which they use to examine how the U.K. government constructed demographic target groups for their advertisements. In the first instance, the target groups seemed to represent a classic illustration of an infrastructure (of online advertising) acting as a source of state power through its design (*cf.*, Mann, 2008; Winner, 1980). However, more closely, this power relationship was exercised in a far less straightforward manner. Instead of observing direct state power in target group practices, Collier, *et al.* found a distributed process where “the targeted advertising platforms acting as a site around which a large ecosystem of actors are involved in a distributed process of experiment, social learning and action, only weakly under the guidance of centrally identified best practice and rules of government communication, permitting the state to exert social power in fairly diverse modes” (Collier, *et al.*, 2024).

Similarly, Chiappini and Ferrari (2024) examined digital money infrastructures from the perspective of their scale, governance goals, and technological design. Noticing that the digital currency industry

undermines conventional institutions' monetary power (and hence potentially the governance of infrastructures), they argued that digital money infrastructures are now increasingly conceived as public utilities and hence 'infrastructural'. Sarkar and Arora (2024) noted that blockchain was not straightforward to be governed by the state by regulation. Instead, the case of the Indian state illustrated that in order to govern blockchain, it first needed to be redescribed and then operated in the fashion of an II, by a network of networks plugging into the state's existing infrastructures.

In the last 10 to 15 years, Internet infrastructures have been and are appropriated or co-opted for the purposes of direct control of content, and more broadly to serve very different functions than their original objectives for which they were designed, to achieve objectives of "governance by infrastructure" (DeNardis and Musiani, 2016). Infrastructural control points, whatever their original function, are understood by a variety of actors as possible intermediaries to regain (or win) control or manipulate the flow of information, ideas (and money) in the digital sphere. If the "smooth running" of the network's technical processes or the management of its flows already have political dimensions, the last decade has led to a proliferation of "new political uses" of certain infrastructures, which differ significantly from the objectives stated at their creation, design, and implementation. This shift has been explored in Musiani *et al.* (2016) on the "turn to infrastructure" in Internet governance. Research addressing governance configurations inscribed in particular technical components of the Internet has since proliferated, including work that links this perspective to the study of technical standardization, using a perspective of "governance through infrastructure."

Overall, Internet governance studies are a telling example of how dynamics of governance of, in and by infrastructure emerge in turn and can be studied with approaches informed by STS, and in a dialogue with cognate disciplines.

This infrastructural perspective on Internet policy and governance is not devoid of concrete policy implications. First, it teaches us that in each case or configuration where governance by infrastructure takes place, it is necessary to conduct identification and explanation work, in order to understand what, precisely, is mobilized as "infrastructure". Is it an element or component that is already identified and clearly established? Is it something that still needs to be "infrastructured" (Karasti and Blomberg, 2018)? Is it an element that needs to be added to an otherwise stabilized infrastructure? Is it an element that needs to be reconfigured for an objective that was previously not envisaged in relation to this infrastructure? In each case, it is the very meaning of the word and the practice of governance that changes. Each case where governance by infrastructure takes place produces a definition of governance, of why we must govern, of how we must (or can) govern — a definition that is not all-encompassing but that must be drawn from the cases. At the current stage of the development of Internet governance as an arena of practices (as well as a field of study), it should rather be noted that a plurality of definitions emerges from different places — physical, software, geographical — of sociological inquiry. It should be emphasized, however, that even if this approach does not allow us to arrive at a definition of governance and the Internet, it allows us to arrive at a set of definitions that are, themselves, very precise each time, and can be mobilized in policy. The detailed exploration of several sites where Internet infrastructures are controversial, diverted, appropriated, claimed is *de facto* a means of investigating what "the Internet" and its "governance" are, the perimeters of which are negotiated on a case-by-case basis.

Implications for further analysis

The exploration of information infrastructures (IIs) offers scope to advance our understanding of the relationship between technological change and power relationships, politics, and governance. The conceptualisation in this paper and the analysis of the contributions indicates this potential and demonstrates that more work needed in several areas. While the smooth operation of the network's technical processes and the management of its flows already have political dimensions, the past decade has


seen a proliferation of new political uses of certain infrastructures, which significantly diverge from their original design and implementation goals. Earlier, we have particularly explored this shift in our work on the ‘turn to infrastructure’ in Internet governance (Musiani, *et al.*, 2016), but now expand upon these premises.

Firstly, given the fiercely empirical nature of the II research tradition, there is a clear imperative for conducting more comprehensive and in-depth field studies. While it is commonplace to advocate for more empirical research in any area, the field of II merits it specifically because the concept of infrastructure is not merely a metaphor but a distinct socio-material form that calls for particular analytical concepts and methodologies. These may help improve our understanding, for example, of how these IIs function, are designed, and used in parallel.

Moreover, the emergence of diverse socio-material forms within specific technological fields underscores the diversity and adaptability of II. These contrasting configurations have profound implications for the types of agencies of the various actors involved (Pipek and Wulff, 2009). This diversity, in turn, underscores the pressing need to more precisely characterize and taxonomize these developments, ensuring that our theoretical approaches are robust and able to consistently interpret and respond to the complex realities shaped by II. Star and Ruhleder’s (1996) concept of infrastructural inversion highlighted the need to pay attention to the often overlooked activities that enable an II to function and the ongoing work of maintenance and repair of breakdown. Pelizza’s (2016) concept of vectorial glance extended this point — arguing the need to address settings, such as pilot sites, where strategic institutional shifts may become visible — and by extension, where there is scope for reconfiguration of lines of authority and accountability that might otherwise be seen as immutable. II studies may thus call into question presumptions about the presumed performativity of IIs and other technologies designed with transformatory intent. The politics of technology may be performed, but whether this happens and if so how is an empirical problem. Rather than inferring the performativity of II it is necessary to explore empirically how the functional and discursive templates of IIs and other technologies may frame and pattern subsequent paths of action.

Secondly, we need more comprehensive middle-range theories that bridge the gap between grand theoretical narratives — such as on AI and ‘digitalisation’ — and the specific empirical findings discussed above. In this sense, recent work on the concept of infrastructuring (Pipek and Wulff, 2009; Blok, *et al.*, 2016; Karasti and Blomberg, 2018) have provided theoretical and methodological insights into understanding infrastructures as processes, practices, and settings that are both expansive and open-ended. This shift from focusing on infrastructures to infrastructuring enables us to recognize field engagements of the researchers and objects of inquiry in a richer way than earlier case-study based ‘snapshot’ studies (*cf.*, Hyysalo, *et al.*, 2019).

Thirdly, and relatedly, there are further opportunities to refine and expand the methodologies used to study IIs. IIs are complex and distributed multi-sited assemblages. All studies of IIs involves methodological simplifications since it is not feasible to study simultaneously all the settings in which an II has been developed, implemented, and used.

These considerations highlight the value of both detailed local studies and the need to expand the focus of enquiry across a range of settings and over an extended duration. However this involves painful trade-offs for researchers managing time and access limitations. This requires researchers to pay careful attention to research design choices, to make them accountable and reflect on the consequences of their methodological choices for what may or may not be discovered (Hyysalo, *et al.*, 2019). Researchers can today draw upon the growing body of work based on explicit research design strategies for conducting specific studies and broader programmes of investigation into IIs that can both improve research design choices and make their consequences more explicit. 

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Notes

[1.](#) MacKenzie and Wacjman, 1985, p. 4.

[2.](#) Hughes, 1983, p. 5.

[3.](#) Hughes, 1989, p. 51.

[4.](#) Mann’s (2008) further argument is more two-directional and joins our interest in governance by infrastructure, though there is only partial alignment between our interests. He stresses a concept of bureaucratic power which is conceived in terms of standardised infrastructure services delivered over a territory by the state and based on depersonalised institutional rationality. That said, it is important to add that this bureaucratic form of power does not merely refer to relations between state elites and government officials. Also relations between the state and civil society are influenced by infrastructural power. These power relations do not merely radiate from the state outwards, but also civil society radiates back to the state. In stable democratic societies, many industrial pressure groups and political parties are allowed to influence the direction of infrastructure development and compete for influence. States can even mobilize citizen commitment to infrastructure development, which has become evident in increasing attempts to win the public acceptance of new infrastructure development projects, often operating through practices of kind of citizen participation (using, for example, public hearing events or citizen juries organised by ministries, but also participatory practices deployed by industrial stakeholders). While clearly two-directional, this conception of power revolves around alliance building but also processes of accommodation, in which more powerful interests have greater room for manoeuvre. The power concept is thereby inherently participatory but not egalitarian. In contrast, governance by infrastructure is a softer form of power. Especially II principally allows for more active citizen roles than conventional technology systems as the uses and designs of II are allowed to develop in tandem (evidenced in energy domain *e.g.*, by Hyysalo, 2021).

[5.](#) Edwards, *et al.*, 2009, p. 365.

[6.](#) Grisot, *et al.*, 2014, p. 200.

[7.](#) Barry, 2006, p. 250.

[8.](#) Karasti and Blomberg, 2018, p. 258.

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