Time for a Decentralization Journey of Digital Infrastructures? Reflections on the 2023 Impact Award[1]

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Digital infrastructures are pervasive. They are pervasive to the extent that "they weave themselves into the fabric of everyday life until they are indistinguishable from it" (Weiser, 1991, p. 94). In fact, for most people in our society, Mark Weiser's vision of the "Computer for the 21st Century" is here today, seductive in its offering of convenient services that make contemporary life possible. In the wake of this development, firms owning successful platforms have emerged as the infrastructure providers of the 21st century. In doing this, they have accumulated such standing that they are among the most valuable[2] companies in the world. They have mastered some of the underlying mechanisms with which infrastructures evolve into successful ones whose positive self-reinforcement serves as a virtuous circle.

Going back in time, early studies offered clues of what would come, both in platform studies (e.g., Parker et al., 2016) and infrastructure studies (e.g., Hanseth & Lyytinen, 2010). In 2013, we documented one such study in a paper entitled "The Generative Mechanisms of Digital Infrastructure Evolution" (Henfridsson & Bygstad, 2013), which now, some 10 years later, has been awarded the MISQ Impact Award. The paper offers a foundation for anyone seeking to explain what makes platform companies successful. In particular, we identified three generative mechanisms[3] by which digital infrastructure evolves: adoption, innovation, and scaling. Simply put, we proposed that more users (adoption), more products (innovation), and more stakeholders (scaling) feed a self-reinforcing process by which infrastructures become increasingly successful over time. In addition, in the spirit of critical realism, we underlined that the activation of these mechanisms is contingent (Bhaskar, 1975/1997), that is, dependent on contextual conditions. We identified loosely coupled architecture and decentralized control as especially significant conditions.

Over the past 10 years, big tech platforms have benefited tremendously from understanding and exploiting these mechanisms. As their users, innovations, and stakeholders have increased manyfold, they have become extensively powerful, often having a more profound impact on our everyday life than nation-states (Lehdonvirta, 2022). Despite the idea of an internet for everyone (e.g., Negroponte, 1995), however, the self-reinforcement of infrastructures has created a Faustian asymmetry of power between platforms and other actors in society. In the wake of this asymmetry, different actors voice ideas of breaking with this platform hegemony and dominance. For instance, starting a few years back, regulators across the world including Europe, the United Kingdom, and the United States have heralded regulatory action grounded in the competitive dominance of big platforms, which has often been perceived as anticompetitive, excessive, and unfair (Jacobides & Lianos, 2021). As an example, consider the European Union's Digital Markets Act Regulation, which entered into force in November 2022 against the backdrop of making the digital economy fairer. The targets of the Digital Markets Act are eight core platform services, including online search engines and video-sharing platforms. All in all, the regulatory action taken is a strategy by which governmental bodies seek to break with the economics of centralized self-reinforcement.

However, there are limits to what antitrust regulation can accomplish in a fast-paced economy where the compounding effect of network effects is at play on a daily basis. In this commentary related to the 10-year MISQ Impact Award for Henfridsson and Bygstad (2013), we discuss a possible direction complementing centralized big tech platforms. We propose a decentralization of infrastructures as a promising avenue for addressing some of the challenges that follow the centralization

[1] This Guest Editorial is invited as part of the terms of the 2023 MISQ Impact Award. The award honors the paper published a decade earlier that the selection committee deems to have had: (1) the most significant and sustained scholarly impact, as shown by citations, by how it led to a change in thinking in the field, and by its prescience in identifying an important issue today; and (2) a real or potential impact beyond academia, especially through how it influences the way our field engages in an important real-world domain. As part of the award, the author is invited to write a reflective editorial on the topic.
[2] In fact, the media has coined the term "magnificent seven," to refer to the seven companies, publicly listed on the S&P 500, with the highest market capitalization including Amazon, Apple, Google, Meta, and Microsoft.
[3] We refer to generative mechanisms as causal structures that generate observable events (Archer et al. 1988; Bhaskar, 1975/1997, 1998).

of power among a handful of platforms. Empowered by Web3 technologies such as blockchain technology and smart contracts, such infrastructures promise a way to reclaim the idea of decentralization in our everyday consumption and production of digital services.

In this editorial, we seek to outline a "decentralization journey" for digital infrastructures as they become enabled by decentralized technologies. To do so, we take our starting point in a reflection upon the generative mechanisms of digital infrastructure that were developed in our award-winning paper. We then offer a problematization of the current hegemony of big tech platforms and propose decentralized autonomous organizations (DAOs) (cf. Ellinger et al., 2024) as a powerful organizational form for instantiating decentralized digital infrastructures.

Digital Infrastructure

Broadly speaking, digital infrastructure refers to the collection of interconnected foundational technologies and information systems that support the operations of digital products, services, and applications. The interest in our discipline in such infrastructure emerged from the observation that (1) stand-alone information systems were becoming increasingly interconnected and that (2) this interconnectedness came with emergent properties that could not be studied without examining the particular information system of interest within its infrastructural context. This directed the focus on interconnected information systems (Hodapp & Hanelt, 2022) and their underlying supporting technologies such as payment infrastructures (Kazan et al., 2018) and the internet (Hanseth & Lyytinen, 2010).

Digital infrastructures are often described as "shared, unbounded, heterogeneous, open, and evolving sociotechnical systems" (Tilson et al., 2010, p. 748). First, digital infrastructures are *shared* in the sense that they are developed to be used by multiple actors to be cost-efficient, interoperable, and highly utilized. Second, they are *unbounded* in that they exist without temporal boundaries and change continuously over time through multiple actions by stakeholders with different design intents. As a digital infrastructure is largely agnostic to the content built on top of it (cf. Yoo et al., 2010), any stakeholder adhering to the infrastructure's immanent set of rules can innovate their own digital products, services, and applications. In doing this, the stakeholder will contribute to the infrastructure's ongoing change. Finally, infrastructures are *open* in that they have low barriers to entry. They are designed to be accessible and interoperable, allowing heterogeneous actors to draw on the infrastructure resources with little restriction.

Shaping digital infrastructures over time, the sheer multitude of heterogeneous actors and technologies makes them complex (Benbya et al., 2020; Lamb & Kling, 2003; Koutsikouri et al., 2018), as systems are introduced over an extended time with varying intentions (Ciborra et al., 2000). As such, efforts to understand the inner workings of infrastructures and the process by which they can be improved, warrant research approaches that recognize their causal complexity. Critical realism (Bhaskar, 1975/1997; Mingers et al., 2013; Sayer, 1992) offers a useful philosophical underpinning for developing such approaches, as it emphasizes the contingent nature of causality (which fits well with the complexity of digital infrastructure). It recognizes that generative mechanisms are not only contingent on the contextual conditions in which they operate but also on other mechanisms at play that might interfere with their operation at any given moment (cf. Elder-Vass, 2010).

The three generative mechanisms (Figure 1) of digital infrastructure identified in our 2013 paper (Henfridsson & Bygstad, 2013) should be understood with this in mind, as they apply to quite different infrastructures (Rodon Modol & Eaton, 2021; Hund et al., 2021). Each one plays a significant role in explaining why a specific infrastructure becomes successful or not. For instance, the adoption mechanism is relevant to understanding how a digital infrastructure feeds from more users who use the infrastructure and its services. The innovation mechanism captures how novel innovations are created as the infrastructure features technical malleability that, in turn, triggers recombination leading to new digital innovations. Lastly, the scaling mechanism illustrates how new partner solutions are added as the infrastructure offers incentives for collaboration.

Importantly, our research suggests that a single mechanism alone cannot explain the successful evolution of digital infrastructure. Just because a particular mechanism has been activated as certain actions in the environment of the infrastructure ignite its causal powers, this typically does not mean that the digital infrastructure will grow without other conditions in place. It often also needs to coincide with one of the other mechanisms, innovation and/or scaling, as a configuration (cf. El Sawy et al., 2010; Pawson & Tilley, 1997) in order to have the causal powers to influence a positive outcome. However, once the mechanisms have kicked in, they exhibit (positive/negative) self-reinforcement where initial success/failure feeds further success/failure.

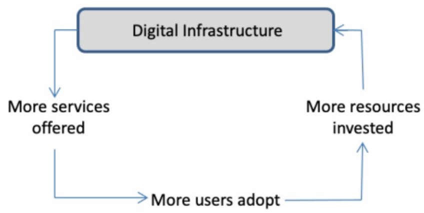
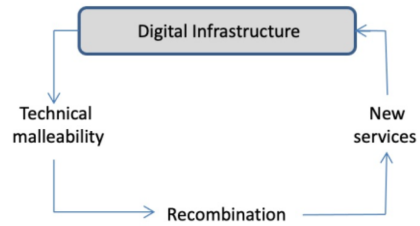
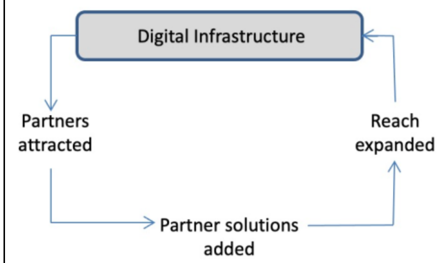
Adoption	Innovation	Scaling
		
A self-reinforcing process by which more users adopt the infrastructure as more invested resources increase the usefulness of the infrastructure.	A self-reinforcing process by which new products and services are created as infrastructure malleability spawns recombination of resources.	A self-reinforcing process by which an infrastructure expands its reach as it attracts new partners by offering incentives for collaboration.

Figure 1. The Generative Mechanisms of Digital Infrastructure (Henfridsson & Bygstad, 2013)

The power of self-reinforcement is manifested in each one of the generative mechanisms of digital infrastructure (Henfridsson & Bygstad, 2013). Regarding the adoption mechanism, more users adopt the infrastructure when more resources are invested in the infrastructure because resource investment increases its usefulness; as the usefulness of the infrastructure increases, more users adopt it, which, in turn, increases the resources invested in the infrastructure. Regarding the innovation mechanism, infrastructure malleability feeds the recombination of resources, which generates new products; as new products are created, incentives to make the infrastructure more malleable for innovators, in turn, make it easier for innovators to recombine digital resources, generating more products. Regarding the scaling mechanism, as infrastructure expands its reach, it attracts new partners by offering incentives for collaboration; as the infrastructure's reach expands, it creates another wave of new partners, with their solutions added to the infrastructure.

The Platformization of Digital Infrastructure

In the past 10 years or so, we have seen a "platformization" of digital infrastructure (cf. Bygstad & Hanseth, 2019). The tremendous success of big tech platforms can, to a large extent, be traced to their intimate understanding and ability to exploit the mechanisms of digital infrastructure. While they did not read our paper, they clearly understand the power of self-reinforcement, as large numbers of users attract even more users, large numbers of products in an ecosystem spawn more innovation, and so on. The self-reinforcement eventually creates significant value, as the asymmetry between inputs and outputs becomes bigger with the network effects. Consider that the value of Apple, as measured by its market capitalization of USD 2.8 trillion (May 6, 2024), is on par with the GDP of the United Kingdom (USD 3.1 trillion, as of 2022) and France (USD 2.8 trillion, as of 2022). In many ways, the network effects of platform companies like the "magnificent seven" may make them more powerful than even nation-states (Lehdonvirta, 2022). No wonder that different stakeholders are voicing ideas about breaking with the hegemony of today's powerful platforms.

Another consequence of the dominance of large-scale platforms is the asymmetric distribution of the total value captured from value-creating activities on the platform. Overall, the distribution of value extracted is typically heavily skewed in favor of the platform owner (e.g., Srnicek, 2016; Zuboff, 2019) as user data is commodified (cf. Alaimo & Kallinikos, 2024). According to Dixon (2024), the value extraction of, for instance, Facebook, Instagram, TikTok, and Twitter is around 99% of the networks' advertising revenues. This relates to the strong network effects associated with these platforms, given the significant pricing power of platform owners. At the same time, this is disappointing since double-sided markets came with a promise that the value creation in each of the platform's markets would benefit platform participants.

Decentralization of Digital Infrastructures

Early writings often manifest the idea of infrastructure as something shared and outside any single stakeholder's control (see e.g., Monteiro, 2000). As such, infrastructures are a type of digital commons (cf. Benkler, 2006; O'Mahony & Ferraro, 2007; Ostrom, 1990), that is, "a pool of digital resources that are shared, accessible, and managed for and by communities to address collective needs" (Ellinger et al., 2024, p. 246). Yet it is clear that many of today's most significant digital infrastructures are corporate in that they are backed or owned by a large business entity. Indeed, despite early examples of clear-cut examples of digital commons in the digital infrastructure space, such as the TCP/IP and HTTP, most recent examples of successful infrastructures with significant growth and scope exercise centralized control. In this regard, it is clear that the contingent condition "decentralized control" (identified in our award paper) has not yet played any significant role as a trigger of infrastructure growth.

In view of this development, one may ask to what extent decentralization is possible in today's digital infrastructures. Are shared, open, and unbounded (cf. Tilson et al., 2010) digital infrastructures something of the past? In answering this significant question, we turn to an organizational form that may serve as a new form of instantiation of decentralized digital infrastructures: DAOs, defined by Ellinger et al. (2024, p. 245) as "collectively owned human-machine systems deployed on a blockchain that self-govern through smart contracts and the voluntary contributions of autonomous community members." Though not without their challenges, DAOs promise to support shared, unbounded, and open infrastructures with the possibility of creating value in the form of convenient services that make future life possible.

First, DAOs are *shared* in that they feature a model for incentives and rewards that motivates individual members of the community to participate in shared governance and decision-making (Tse, 2020). In particular, tokens play a significant role here as they incentivize active participation in decision-making and contributions. They provide the basis for individuals to take ownership of the common infrastructure resources and participate in voting on proposals for change (Zhao et al., 2022). Second, DAOs are *unbounded* in several ways. They develop over time as a reflection of stakeholders' participation in the development of new services based on, for instance, smart contracts (cf. Gregory et al., in press). Third, DAOs are also *open*, as they exhibit permissionless participation, where anyone who is a token holder can contribute to shaping the direction of the DAO through the decentralized governance process. Each member, whether developer, investor, or user, can join (or leave) and vote on governance proposals without consideration of background, location, or interests.

Clearly, while DAOs check many of the boxes for decentralizing digital infrastructure, it is relevant to question the nature of the consequences for the evolution of digital infrastructure. To what extent do the generative mechanisms of digital infrastructure apply to decentralized infrastructures such as DAOs? We do think that the original model offers explanatory power related to the evolution of DAOs, especially when examining DAOs together with their underlying blockchain technology. Taking the example of MakerDAO (Ellinger et al., 2024), which supports automated lending and borrowing, the rapid adoption of the stable coin, DAI, can be explained by how the increasing resources generated from user adoption have been invested in improving MakerDAO's technology and offer to the user, which, in turn, has led to further adoption (the adoption mechanism). Furthermore, considering that MakerDAO is built on the Ethereum blockchain, recombination is facilitated by Ethereum's open source libraries, standardized token protocols, and access to external providers of data needed for smart contracts (the innovation mechanism). With further services built on the Ethereum blockchain, further and improved resources can be added for potential use by smart contract developers such as MakerDAO. Lastly, as MakerDAO's stable coin, DAI, has become a viable option for international remittances, it has also been adopted by decentralized applications such as Aave and Compound. More partners have since been added with wider reach, including payment processors and NFT exchanges such as OpenSea (scaling mechanism).

Conclusion

Since the publication of the 2013 paper, the evolution of digital infrastructures highlights both the transformative potential and challenges posed by their increasing platformization. While the generative mechanisms of adoption, innovation, and scaling have driven the success of big tech platforms, they have also led to centralized control and power asymmetries. The resulting concentration of power among a few large technology companies necessitates the exploration of complementary approaches that align with the original ideals of shared, unbounded, and open infrastructures.

As we argue in this editorial, DAOs represent a promising direction for the decentralization of digital infrastructures through technologies like blockchain and smart contracts. DAOs enable a viable decentralized design for infrastructures, with the potential to improve privacy, governance, cooperation, and security. Going forward, even though DAOs represent a powerful step toward reclaiming control and reshaping infrastructures to be more shared, open, and unbounded, they come with significant challenges. Information systems researchers with an interest in digital infrastructure and platforms are especially well-positioned to research these promises in light of such challenges.

Senior Editor Reflections—Alistair Mutch, Nottingham Trent University

It is a great pleasure to, first of all, congratulate Ola and Bendik on this richly deserved award, and, secondly, to have the opportunity to reflect on the special issue in which it appeared. I recall it being a challenging process as we initially wondered whether we would attract submissions of the quality required for the journal, and then, when we received a range of excellent submissions, whether we would be able to put together an editorial team to support us. This is a good opportunity to pay tribute to the excellent work of that team in general, and Donald Hislop in particular, who shepherded this article through the process.

I also wish to thank my fellow guest editors, John Mingers and Leslie Willcocks, for inviting me to join them. It was they who persuaded the journal to give us the opportunity—the first, as I understand it, in a major journal, to invite submissions engaging with critical realism. That the journal was justified in taking what was a bold step at the time can be seen not only in the excellence of Ola and Bendik's article that this award testifies to but also in the healthy citation numbers that the special issue has attracted. One of our aims when putting together the special issue was to build on some pioneering work by others to show how ideas drawn from a philosophical tradition that might be unfamiliar to many could help engagement with real-world problems. Since the publication of the special issue, work has appeared that helps translate what can seem unfamiliar, not to say daunting, bodies of work into guides for practical work. I am thinking here, in particular, of the edited book *Studying Organizations Using Critical Realism: A Practical Guide* (Edwards et al., 2014) but there is much other work that is beyond the scope of these brief comments that provide exemplars for others to follow. At the same time, however, I am also conscious of the widespread use of alternative approaches to the study of information systems in organizations, such as sociomateriality. I have myself used ideas from critical realism to suggest why I do not find these persuasive for practical analysis of the world, but the debates continue (Mutch, 2013). For me, examples such as those provided by Ola and Bendik in their original article, as well as their very helpful observations in their editorial comments, show the enduring value of ideas drawn from the critical realist tradition in our endeavors to understand the world and its complexities.

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