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Infrastructure studies meet platform studies in the age of Google and Facebook

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Abstract

Two theoretical approaches have recently emerged to characterize new digital objects of study in the media landscape: *infrastructure studies* and *platform studies*. Despite their separate origins and different features, we demonstrate in this article how the cross-articulation of these two perspectives improves our understanding of current digital media. We use case studies of the Open Web, Facebook, and Google to demonstrate that infrastructure studies provides a valuable approach to the evolution of shared, widely accessible systems and services of the type often provided or regulated by governments in the public interest. On the other hand, platform studies captures how communication and expression are both enabled and constrained by new digital systems and new media. In these environments, platform-based services acquire characteristics of infrastructure, while both new and existing infrastructures are built or reorganized on the logic of platforms. We conclude by underlining the potential of this combined framework for future case studies.

Keywords

API, applications, Facebook, Google, infrastructures, networks, Open Web, platforms, programmability, STS

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Until recently, scholars of media have been satisfied with a short list of objects of study. For researchers interested in conduit and not content, each medium was a technology and also a surrounding "environment" (Meyrowitz, 1997: 60) of objects, audiences, producers, distributors, laws, communities, and companies. Every medium proved capacious and lasting as a category and created its own tradition of inquiry: radio studies, film studies, telecommunications, television studies, and computer-mediated communication. The advent of digital technologies and the Internet challenged this epistemology. Increasingly subdivided media objects seemed to require an increasingly subdivided media theory. For example, video games were initially categorized as "interactive television," but when the characteristics of video games diverged from those of television, this term became ungainly, and specific research emerged to target the new media object. Similarly, Tinder, electronic mail (email), and numerically controlled machine tools all involve "computing," but it is not obvious that they should all be analyzed in the same way. Scholars turned to new concepts to acknowledge the heterogeneity of media.

Two theoretical approaches have emerged as potential candidates to contain and characterize the new digital objects of study in the media landscape: *infrastructure studies*, emerging from science and technology studies and information science, and *platform studies*, centered in media studies. The former has focused on analyzing essential, widely shared sociotechnical systems. Using case studies ranging from electric power grids (Hughes, 1983) to communication networks (Graham and Marvin, 2001) to scientific "cyberinfrastructures" (Edwards et al., 2007), this school of thought has highlighted key features of infrastructure such as ubiquity, reliability, invisibility, gateways, and breakdown. By contrast, platform studies explores how computing devices (such as Intel-chip-based PCs) and software environments (such as gaming systems) affect the characteristics of application software built upon them. In media studies, the concept of "platform" has been extended from game design (Montfort and Bogost, 2009) to content-sharing websites (Gillespie, 2010; Helmond, 2015) and social media applications (Langlois and Elmer, 2013; van Dijck, 2013). Key features discussed in platform studies include programmability, affordances and constraints, connection of heterogeneous actors, and accessibility of data and logic through application programming interfaces (APIs).

Both infrastructure and platform refer to structures that underlie or support something more salient. Yet their different conceptual frameworks and separate origins obscure the relationship between them. Are the infrastructure and platform perspectives complementary, opposed, or completely unrelated? Or do they overlap, revealing different aspects or elements of the same set of objects? Do they describe different stages on a timeline in which some platforms evolve into infrastructures, or do they oscillate over time in some pendular cycle?

Consider Google, which we analyze in greater depth below. Google exemplifies features found in both literatures. Apps such as Google Maps can be considered programmable platforms on which users and developers can build new digital objects. At the same time, Google's web search has become so ubiquitous and deeply embedded that it could be seen as an infrastructure: robust, widely shared, widely accessible, and essential. Any breakdown in Google's services would substantially disrupt daily life and work. What is Google, then: a platform? An infrastructure? Is it sequentially or simultaneously both?

Here, we demonstrate that cross-articulating these two perspectives can improve our understanding of digital media. After reviewing both literatures, we show that boundaries between the two perspectives have become increasingly blurry. Digital technologies have made possible a "platformization" of infrastructure and an "infrastructuralization" of platforms. Articulating the two perspectives highlights the tensions arising when media environments increasingly essential to our daily lives (infrastructures) are dominated by corporate entities (platforms). Next using case studies of Facebook and Google, we demonstrate that infrastructure studies provides a valuable comparative approach to widely accessible services of broad public value, a perspective not provided by platform studies. At the same time, platform studies, with its focus on rapidly evolving digital artifacts, shows how expression, communication, and knowledge are constrained within profit-driven corporate ecosystems. We conclude by underlining the potential of this combined framework for future research.

Digital environments in infrastructure and platform studies

Infrastructure studies: from systems to networks to webs

Infrastructure studies developed along two main intellectual lines. The first sought a historical perspective on large technical systems (LTS). Historians and sociologists used that perspective to analyze systems ranging from electric power grids to telephone networks to air traffic control (Bijker et al., 1987; Hughes, 1983; Mayntz and Hughes, 1988). In this perspective, infrastructures often originate as sociotechnical *systems* that are centrally designed and controlled, typically in the invention and development phases of new technologies. In these phases, they remain the province of their developer(s), whether a single individual, a team, or an enterprise. Once these systems begin to travel in physical and social space, they also begin to change. Both users and other developers may modify or extend them while competing technologies and enterprises arise; consider the many similar, but incompatible devices and standards developed during the early days of railroads, electric power, or digital computers. Consequently, when a need arises to link heterogeneous systems into *networks*, devices, and/or social apparatuses known as *gateways*—for example, AC/DC power converters, software/hardware combinations such as Ethernet, and legal arrangements such as international trade law (Egyedi, 1996; Egyedi and Spirco, 2011)—must be created. The network phase signals not only the involvement of many more actors but also growing social commitments manifested in, for example, explicit standards, user habituation, and organizational routines. Some infrastructures, such as electric utilities or postal services, acquire the character of public goods, with governments or highly regulated monopoly firms taking responsibility for development, operations, and/or maintenance.

In later phases of development, *webs* or *internetworks* (networks of heterogeneous networks) may form. For example, trucking, rail, and shipping networks developed independently, but were later integrated into a global internetwork by means of the International Organization for Standardization (ISO) standard shipping container, a classic example of a gateway (Busch, 2011; Egyedi, 2001; Klose, 2015). The Internet itself is a network of heterogeneous computer networks, made possible by the Transmission

Control Protocol/Internet Protocol (TCP/IP). Because they integrate many semi-independent systems, internetworks can only rarely be designed, controlled, or standardized from above (Edwards et al., 2007); instead, fully developed infrastructures are complex ecologies whose components must continually adapt to each other's ongoing change. In a final, devolutionary phase, infrastructures can splinter into more specialized elements or die altogether (Graham and Marvin, 2001; van der Vleuten, 2004).

A second intellectual stream in infrastructure studies, championed by Star and Bowker, elaborated the phenomenology and sociology of infrastructures (Edwards et al., 2007, 2009; Graham and Marvin, 2001; Ribes and Finholt, 2009; Star and Ruhleder, 1996). They articulated, for example, interacting dependencies on infrastructures, which create potentials for social chaos during episodes of breakdown, such as urban blackouts or major Internet outages. Dependency stems from the qualities of ubiquity, reliability, and especially durability; major infrastructures such as railroads, telephone networks, Linnaean taxonomy, and the Internet endure over many decades, even centuries. As a result, infrastructures are "learned as part of membership" in communities, nations, and lifeworlds (Bowker and Star, 1999; Edwards, 2002). This stream of infrastructure studies emphasizes the critical role of infrastructure's human elements, such as work practices, individual habits, and organizational culture, as well as the ways an infrastructure can structurally exclude some people (e.g. deaf, blind, or wheelchair-bound individuals) from purportedly "universal" services (Lee et al., 2006; Ribes and Bowker, 2008; Ribes and Finholt, 2009).

Platform studies: from programmability to application ecologies

The study of platforms is a more recent and more cacophonous endeavor. The computer industry adopted the term "platform" in the mid-1990s, when Microsoft described Windows as a platform and Netscape defined a "cross-platform" strategy for its web browser. Management and organization studies researchers identified platforms as critically important for both digital and non-digital industries. For these scholars and the business cultures they examined, platforms are architectures comprising three key elements: core components with low variability, complementary components with high variability, and interfaces for modularity between core and complementary components (Baldwin and Woodward, 2008). Such architecture can lower the cost of innovation because it avoids building an entirely new system for each new product (Baldwin and Woodward, 2008: 8–9). For management and organization studies, then, platforms constitute a powerful model for innovative products, with direct applications to digital media.

Media scholars' interest in digital platforms coincides with the rise of "Web 2.0" (O'Reilly, 2005) in the mid-2000s. Researchers studying the Web extended the computer industry's notion of platform to web-based applications whose technical architecture emphasizes the provision of connection, programmability, and data exchange with applications developed by others. Products of this interoperability came to be known as "mashups," in which a new application or service is created by aggregating two or more data sources. Scholars soon began to interrogate the political and cultural implications of these participatory forms of production and remix of content. Precursors to platform

studies include Benkler's (2006) investigation of peer production in the "networked public sphere" and Jenkins' (2006) study of how digital remixing practices alter the traditional boundary between producers and consumers of cultural content.

Platform studies scholars similarly focus on participatory media practices, but acknowledge more directly the dual nature of commercial platforms: their affordances support innovation and creativity—supplying a base for video games or new media forms—yet simultaneously constrain participation and channel it into modes that profit the platform's creators. According to Bogost and Montfort, platforms' essential characteristic is the programmability which permits users to go beyond the original designers' project. A sound bite states, "If you can program it, it's a platform. If you can't, it's not" (Andreessen, 2007, quoted in Bogost and Montfort, 2009). This usage of "platform" is clearly compatible with the management and organization studies usage mentioned above; Montfort and Bogost essentially describe the 1977 Atari Video Computer System (VCS) as a core component whose interchangeable game cartridges act as complementary components—a groundbreaking rupture with that era's hulking wooden-cabinet arcade machines, each of which offered just one game.

In some of this scholarship, the analysis of platform architecture and design is complemented by a focus on users' agency as expressed in the economic and legal characteristics of platforms. Here, cultural studies and political economy meet, exploring individual expressions while interrogating the power relations typical of commercial platforms. José van Dijck, for example, defines platforms as a "set of relations that constantly needs to be performed," in part due to continual friction between, on one side, users' goals of expression and, on the other side, platforms' profit-seeking aims and the legal surround that defines legitimate use (van Dijck, 2013: 26). Similarly, Langlois and Elmer critically assess "some of the new forms of power yielded by corporate social media platforms" such as Facebook (Langlois and Elmer, 2013: 14). Economic interests, they write, affect the design of social media interfaces (e.g. integrated systems for displaying online ads targeted to individual users). More fundamentally, social media platforms bind pre-defined communicative acts to an economic logic. For example, "like," "share," and "retweet" not only provide a means for users to express themselves but also facilitate ranking, product recommendations, and data analytics. Analyzing corporate social media platforms therefore requires researchers to investigate these "double articulations" (Langlois and Elmer, 2013). For example, corporations' goal of gathering users' personal data determines the technical properties of platforms, which in turn shapes how they organize communication among users.

Gillespie similarly analyzes the tensions between agency and architecture in platforms by studying how the legal constructions and technical affordances of digital intermediaries shape public discourse. Using YouTube as a case study, he highlights how social media companies deploy the term "platform" to position themselves as neutral facilitators and to downplay their own agency: "platform" is "specific enough to mean something, and vague enough to work across multiple venues for multiple audiences" (Gillespie, 2010), such as developers, users, and advertisers. Recent debates about the legal responsibilities of Uber and AirBnB illustrate this strategy: the firms present themselves as platforms, "merely" connecting car or property owners with potential customers.

To summarize, platform studies scholars explore how modularity and power are negotiated between a core unit with low variability and heterogeneous components of high variability. Their perspective is cultural, economic, and critical, forming a continuum ranging from cultural studies to political economy. Collectively, they highlight how platforms' affordances simultaneously allow and constrain expression, as well as how technical, social, and economic concerns determine platforms' structure, function, and use.

Beyond the specific frame of platform studies, the dialogue between infrastructure studies and media studies writ large is already considerable. The "new materialists" (Sandvig, 2013) comprise scholars focusing on how media infrastructures interact with media cultures. Scholarship on cinema networks in urban Nigeria (Larkin, 2008), undersea Internet cable networks (Starosielski, 2015), or the cultural imaginaries of data centers (Hu, 2015) illustrate this rising body of scholarship on "media infrastructures" (Parks and Starosielski, 2015). We describe next how we take part in this cross-disciplinary articulation.

Platformized infrastructures and infrastructuralized platforms

The brief overview offered above cannot possibly do justice to the richness of these two approaches. Instead, we have deliberately emphasized the historicist component of infrastructure studies and the critical focus of platform studies. In this section, we combine these two frameworks, putting the rise of platforms into historical context while highlighting their consequences for communication, expression, and knowledge. We argue that the rise of digital technologies, in a neoliberal, political, and economic climate, has simultaneously facilitated a "platformization" of infrastructures and an "infrastructuralization" of platforms.

A historical and critical perspective on the rise of platforms

Moving towards a combined framework, we first need to describe the difference between platform builders and the "system builders" central to Thomas Hughes and the STS theory of infrastructure we described earlier. One might regard the former as an instance of the latter, except for one key difference: unlike system builders, platform builders do *not* seek to internalize their environments through vertical integration. Instead, their platforms are *designed* to be extended and elaborated from outside, by other actors, provided that those actors follow certain rules. Platforms such as Apple's iOS (iPhone operating system) or Google's Android achieve their success precisely by attracting many independent actors to contribute to their software ecologies, instead of attempting to build and market stand-alone products. Users benefit from the platform's standardized interface, while independent developers benefit from the platform's code base, large audience, and marketing power. Meanwhile, the platform builder reaps profits due to increased buy-in (or lock-in) by both sides. The costs of this approach, as platform studies has shown, come in the form of constraints, constant revisions forced by platform updates, and lock-in to the platform's conception of users, functionality, and design values. Finally, because achieving lock-in is among platform builders' principal goals, most

Table 1. Table summarizing infrastructure and platform properties.

	Infrastructure	Platform
Architecture	Heterogeneous systems and networks connected via sociotechnical gateways	Programmable, stable core system; modular, variable complementary components
Relation between components	Interoperability through standards	Programmability within affordances, APIs
Market structure	Administratively regulated in public interest; sometimes private or public monopoly	Private, competitive, sometimes regulated via antitrust and intellectual property
Focal interest	Public value; essential services	Private profit, user benefits
Standardization	Negotiated or de facto	Unilaterally imposed by platforms
Temporality	Long-term sustainability, reliability	Frequent updating for competitive environment
Scale	Large to very large; ubiquitous, widely accessible	Small to very large; may grow to become ubiquitous
Funding	Government, subscription, lifeline services for indigent customers, pay-per-use (e.g. tickets)	Platform purchase (device), subscription (online), pay-per-use (e.g. TV shows), advertising
Agency of users	"Opt out," for example, going off the grid	"Opt in," for example, choosing one platform instead of another; creating mashups

API: application programming interface.

actively discourage the construction of gateways—to borrow an infrastructure studies concept—which might permit interoperability with competitors. This strategy forces independent developers either to commit to just one platform or to build and maintain multiple versions of the same product.

As characterized in the literatures reviewed above, platforms and infrastructures have some similarities, but they differ in scale and scope. Evolving from systems to networks to webs, infrastructures integrate many heterogeneous components by means of sociotechnical gateways. As essential elements of everyday life and work, many infrastructures are widely accessible, some to the extent of being funded, managed, and/or regulated by governments. In general, platforms are built with smaller scales and scopes in view. Platform builders seek to create modular frameworks. The platform remains a centrally controlled and designed system (often under corporate control), but benefits from the innovations of a large penumbra of third-party developers.

Table 1 presents these concepts as mostly distinct, but it also shows respects in which they overlap. As we will now discuss, these boundaries have become increasingly blurry.

Platforms rise when infrastructures splinter

Perhaps unsurprisingly, both computer industry and media studies' ideas about platforms originated in a period when the phenomenon Graham and Marvin (2001) have called the

"modern infrastructural ideal" was disappearing. Their felicitous phrase calls out the tacit, imperfectly realized, yet widespread ideal, originating around the middle of the 19th century, of cities as coherent units responsible for providing certain services to all citizens, for example, roads, sewers, emergency services, and public transportation. Many of these infrastructures originated as private enterprises, later acquiring the status of publicly regulated monopolies. Around the same time, national governments also became involved in the provision and/or regulation of railroads, major highways, post/telegraph/telephone, and other infrastructures—including the early Internet. Starting in the late 1970s, however, the modern infrastructural ideal began to collapse as neoliberal leaders sought to lower costs through market competition. Many infrastructures underwent deregulation and/or privatization during the Thatcher–Reagan era; as a result, they often "splintered" into numerous enterprises. The government's role was no longer to run or oversee monopoly providers of public goods, but rather the reverse: to break those monopolies apart so as to increase competition while renouncing many of the responsibilities implied by the modern infrastructural ideal. This strategy often produced efficiencies, but it also resulted in tiered structures of vestigial, poorly functioning services for low-income citizens alongside premium services for the wealthy.

A striking view of the modern infrastructural ideal's decline, and its replacement by fragmented, privatized, yet interoperable systems and services, can be seen in the history of networked computing. In the 1960s, the rising sense that computer power might become a significant resource for large numbers of people led numerous analysts to the concept of "computer utility." Computer utility would build and operate giant computers whose central processing unit (CPU) time could be shared, in the same way that electric utility customers share huge power plants. The resulting economies of scale, they argued, would keep prices low and ensure sufficient computer power for almost any task, provided on demand. This analogy made perfect sense in an era when a single high-end computer could cost US$100,000 or even much more. And in fact, a number of companies pursued this model in the late 1960s. A few, such as CompuServe, became very successful. Observers anticipated that such services might eventually become public, regulated monopoly utilities—in other words, an infrastructure (Campbell-Kelly et al., 2014; Edwards, 2010; Greenberger, 1964).

And indeed, the first 20 years of Internet history, from the late 1960s through the late 1980s, were marked by all the features of the modern infrastructural ideal: heavy government investment, sponsored first by the US Defense Department's Advanced Research Projects Agency and then by the US National Science Foundation (NSF) in the public interest. In the 1980s, the NSF forced the broad provision of Internet connections in order to permit scientists at less well-resourced institutions to share time on the costly supercomputers it purchased for a few major research centers—exactly the "computer utility" model. The French Minitel system, introduced in 1980 and reaching 6.5 million French citizens by 1990 (far more than any commercial networking service), represents perhaps the most complete realization of the computer utility model as a public good (Cats-Baril and Jelassi, 1994).

Beginning in the late 1980s, that model was abandoned, and along with it, any notion of public provision (although the government did retain some regulatory authority). Many factors (among them the rapid, largely unanticipated rise of personal computing)

produced this change, yet the retreat from the modern infrastructural ideal and the rise of neoliberalism certainly played major roles. The crucial final steps in this splintering process were privatization of Internet backbone lines (from 1987) and deregulation (removal of restrictions on commercial use, from 1992).

Currently reaching nearly 2 billion people, the Internet—which includes the World Wide Web and cloud computing—clearly exhibits all the features of an infrastructure. It is reliable, transparent, widely shared, and visible to users mainly when it breaks down. Its many uses are learned as part of membership in contemporary society. It provides essential services, so much a part of commerce, government, work, and everyday life that whole societies would be crippled if some catastrophe caused it to collapse. Most governments regulate Internet provision to some extent; some, such as Estonia, even offer universal Internet connectivity as a public utility. Yet where service is splintered among many for-profit providers, as in the United States, many low-income citizens remain excluded, and their exclusion is both deeply consequential for them and invisible to the dominant culture.

The history of networked computing resources can thus be seen as the transformation of a traditional monopoly infrastructure model into the deregulated, privatized, and splintered—we might say "platformized"—infrastructure model so prevalent in many sectors today (Abbate, 1999; Edwards, 1998; Kahin and Abbate, 1995; Kahin and Keller, 1997). Computing and computer networks arguably contributed heavily to the splintering of other infrastructures as well, by permitting fine-grained, swifter, and more sophisticated management of large enterprises (Castells, 2000). For example, older, more monolithic media infrastructures such as cable TV companies are now waging battles against emergent Internet-based "set-top box" platforms such as Apple TV, Amazon Fire, or Google Play, which permit "à la carte" media provision.

To summarize, the rise of ubiquitous, networked computing and changing political sentiment have created an environment in which platforms can achieve enormous scales, co-exist with infrastructures, *and in some cases compete with or even supplant them*. Platforms themselves remain a centrally designed and controlled system (Edwards et al., 2007), but the platform ecology looks more like a network or web, linking independently developed and maintained systems (e.g. apps). In the following section, we analyze Facebook and Google as cases of this combined infrastructuralization of platforms and the platformization of infrastructures.

Reaching out and locking in: Facebook, Google, and the Open Web

Infrastructure studies and platform studies each provide useful analytical tools for understanding the fraught relationship that currently exists between the public-oriented Open Web and locked-in "walled gardens." We contrast Facebook and Google with the Open Web to demonstrate the contemporary convergence of platforms and infrastructures.

The Open Web, Facebook, and the API

What we call here the "Open Web" refers to the original conception of World Wide Web architecture, which was based on four technical components: Hypertext Transfer Protocol

(HTTP), uniform resource identifiers (URIs, sometimes called "locators" or uniform resource locators [URLs]), Hypertext Markup Language (HTML), and hyperlinks (encoded in HTML) (Berners-Lee and Fischetti, 1999; Jacobs and Walsh, 2004). All of these components exist as publicly accessible, communally regulated standards (Fielding et al., 1999). These Open Web protocols can be leveraged to do three kinds of things:

- Publish content using open standards and refer to it using open identifiers (URIs);
- Write code that facilitates access to that content by a variety of "agents" (both humans and software robots/crawlers);
- Reuse, re-aggregate, and repurpose content to constitute new information resources (Celik, 2010).

As a result of its technically open architecture (Jacobs and Walsh, 2004), the Web is decentralized and without technically defined or technically enforced boundaries. That architecture, essentially a common transaction protocol (HTTP) and naming scheme (URI), presents a flat content space permitting uniform access by humans and computational agents through browsers and other web-based apps (e.g. Google's web crawler) and unmediated hyperlinking. Open Web–based resources need not be free—they are routinely created for profit and some must be paid for. Yet the Open Web is "Open" because the technical and institutional arrangements of the system permit anyone to create visible, findable, and linkable content that is encoded using public standards.

The historical development of the Web, its feature set, and its pervasive presence are characteristic of phenomena well-described by infrastructure studies. The Web creates interoperability among a huge variety of distributed, heterogeneous computers and content resources. This interoperability is based on open standards that have evolved over 25 years of Web history through negotiation and incremental improvement. The Web is effectively a global commons, largely beyond the control of any particular corporation or government. Finally, the Web is embedded in everyday life and practice. With entertainment, finance, health, education, and so much else now "on the Web," Web access has become as crucial to modern social life as electricity, telephones, and sewers.

Clearly, then, the Web is an infrastructure. Yet, the platform studies perspective also provides crucial insights. For example, platform studies emphasizes programmability as a defining characteristic. Advocates of the "programmable web" (Swartz, 2013) have described how open standards such as HTTP, URIs, and HTML comprise a flexible, extensible platform on which a myriad of applications can be built. To them, the openly addressable content of the web constitutes a huge database that can be exploited by such applications.[1] A commonplace example are news aggregators, which collect content from numerous sites using the Rich Site Summary (RSS) open standard. Because this programmability relies on Open Web principles, the Web-as-platform is "free, as in free speech" (Free Software Foundation, 2016), in the sense that its protocols permit anyone to publish, code, link to, or consume its resources, without constraints other than cost. In its early years, much of the web's richness and vitality stemmed from the combination of its powers as a platform and its (then) relative independence from the economic logics of private ownership. In its first decade, the Open Web competed directly with private online dial-up services established in the 1980s, such as CompuServe, Prodigy, and

American Online. Like the Minitel system in France, these walled-garden platforms provided many kinds of information and other services, but initially prevented their clients from accessing the Internet at all. Later, they offered limited, curated sets of web- or Internet-based resources while preventing access to the rest. Finally, after struggling to reinvent themselves in the 2000s, the surviving companies abandoned the walled-garden approach, which could no longer compete with the vast variety of content and services available on the Open Web.

With this history in mind, we next observe that Facebook's huge reach and its embeddedness in daily life lend it, too, some of the properties of infrastructure. These same properties also make Facebook a formidable force in a profit-motivated "platformization" (Helmond, 2015), which is beginning to eat away at the foundational promise of the Open Web. This platformization entails moving away from published URIs and open HTTP transactions in favor of closed apps that undertake hidden transactions with Facebook through a Facebook-controlled API.

Like electrical sockets, APIs permit other programs to "plug in," in order to exchange data or perform other functions; unlike electrical sockets, however, APIs create a two-way flow of data. In the language of infrastructure studies, an API is a gateway, permitting other systems to interact with Facebook to form a seamlessly interactive network. The e-commerce companies Salesforce and eBay released web APIs as early as 2000. By the mid-2000s, web APIs were proliferating rapidly (Flickr in 2004, Google Maps in 2005, and Twitter and Facebook in 2006).

APIs are not used exclusively in commercial platforms; they are an increasingly common protocol in governmental open data initiatives. However, Langlois and Elmer (2013) show that the Facebook API represents a double-edged sword. On one hand, it increases the functionality of the Facebook platform by enabling an ecology of apps using the API to exchange data with Facebook. On the other hand, the API creates notable restrictions and consequences for both app developers and users. Rather than connecting them to the Open Web, the API locks both groups into a landscape defined and controlled by Facebook, A critic holds that Facebook's turn away from the Open Web architecture of URIs and repeatable HTTP transactions in favor of "walled gardens" is "suffocating the Internet as we know it" (Holmes, 2013).

Consider the RSS-based news aggregators mentioned above. Facebook has recently invested significant resources to host news sources, including high-profile ones such as the *New York Times* (Somaiya et al., 2015). If successful, this approach might eventually pull some of those sites' content out of the Open Web ecology—where it was addressable for access and linking by an open URL and available to aggregators and other Web-based applications such as search engines—into the Facebook ecology controlled and recorded by the Facebook API, with potentially severe limits on access outside the boundaries of that ecology. Of note, some of these same news sources had previously attempted their own version of the walled-garden approach, placing their content behind paywalls. Their current negotiations with Facebook might be said to reflect their capitulation to the platform strategy—recognizing, in effect, that their stand-alone systems cannot compete with a dominant platform ecology.

Through this self-defined and self-serving walled garden, Facebook is emerging as *the* social network monopoly in some markets. With an over 60% share of all social

media transactions worldwide, Facebook looks more and more like a de facto infrastructure. Clearly, Facebook has long sought to embed itself in everyday life; everyone "should" have a Facebook presence, not just for communication but for organizing and extending one's social relations and one's online connectedness more generally. Facebook works to achieve ubiquity and taken-for-grantedness not only by creating expectations for users' *deliberate* Facebook activity, such as friending people or posting photos, but also through the many actions users perform—*but never intentionally or explicitly choose*—by engaging the Facebook API. For example, when users authenticate to websites or applications using their Facebook identities, the API records these acts to their Facebook data profiles. Having access to this identity, many applications then silently contribute to the Facebook social graph via the API, extracting data from our shopping habits or information-seeking behavior and sending it along. Facebook then uses these data traces to tailor advertising and adjust newsfeed priorities, among other customizations to our personalized walled gardens.

Viewed simultaneously as an infrastructure and platform, Facebook presents a disturbing image. As an infrastructure, Facebook is progressively expanding and embedding itself in our daily existence, taking over more and more functions formerly provided by other, less restrictive means. The API, as a gateway, transforms Facebook from a centrally controlled system into something more like a network of independently developed, yet seamlessly interconnected systems and services. As a proprietary, largely opaque platform, Facebook filters our daily communicative acts through a profit-extracting sieve, deploying its intimate view of users' activities and relationships for the benefit of advertisers and others, who in turn provide further data (via the API) for the Facebook social graph. As a result, its power to shape our communication behavior for its own ends increases.

Knowledge as programmable object: Google

What role does Google play in the Internet? Consider the company's oldest and most basic service—search. At the time of this writing, Google accounts for over 65% of all web searches worldwide, trailed by Bing (13%), Baidu, and Yahoo (9% each).[2] This lopsided tally falls even more heavily in Google's favor in the United States (85%) and Europe (92%).[3] Search is among the Internet's most vital technologies, rendering Open Web resources findable and accessible. In addition, the company provides Internet-based applications, including those most vital to the large majority of users: email, documents, spreadsheets, maps, YouTube videos, and cloud storage. These services have drawn Google's users into ever deeper reliance on its services. In recent years Google has marketed these same services to businesses and universities (including one of our own), in many cases replacing legacy licensed software from multiple providers with the suite of Google Apps.

From one perspective, then, Google looks like an infrastructure. Using Open Web protocols, it connects many independent systems into a robust, reliable network at the level of information content (at least from the user's viewpoint). It is embedded in the background and widely accessible. If Google were to vanish tomorrow, large numbers of people would find their lives substantially disrupted, with their email archives and

addresses, documents, navigation, photos, and other critical records and services either entirely gone or requiring substantial effort to reconstruct. The company's unprecedented dominance across Europe has led to a European Union antitrust investigation.[4] For good or ill, Google's near-monopoly on search creates a uniform, invisible, and robust infrastructure for accessing the vast store of knowledge and information on the Open Web.

On the other hand, looking at Google through the lens of platform studies highlights programmability as the very basis of Google's success. Like other Web 2.0 phenomena, Google's systems are "native web application[s], never sold or packaged, but delivered as a service" (O'Reilly, 2005). The Web 2.0 model is based on connecting actors and content, permitting the construction of new web-based applications. A revealing example is the case of digital maps (Plantin, 2015). Digital cartography originally required specialized geographic information systems (GIS) software and access to national government maps (such as Ordnance Survey in the United Kingdom or IGN in France) or maps from an aerial imagery company (such as Teleatlas or Navteq). Reuse of maps was hindered by high cost, complex technical architectures, and strict copyright. In 2005, Google released Google Maps and almost immediately provided an API. The API permitted third parties to add or overlay other data onto the Google base map, thus creating mapping "mashups." In other words, Google transformed maps into *programmable objects*, with Google Maps as the platform. Similar examples are proliferated via the addition of APIs to most Google products. As with Facebook, the principal benefits to Google are the user activity data returned by the API and the ubiquity of its branded interface, while the myriad applications connected to the Google platform benefit from the ability to build on Google-provided data.

Seen as a platform, Google presents issues similar to Facebook. Because it designs and controls Internet search, the company holds enormous power over the visibility of web-based resources. While Google (to its credit) goes to considerable lengths to prevent the gaming of its search algorithms—for instance, Google asserts that no one can pay to increase a web page's rank, except via "sponsored links" clearly labeled as such—many strategies exist for raising that rank. Some companies' entire business consists of helping others improve their position in Google search results. Given that other search platforms, such as Baidu, appear to permit even greater outside influence over their algorithms—in Baidu's case, greatly restricting the prevalence of results from sources outside China—Google is perhaps the "lesser evil," but its profit-driven private near-monopoly still remains a substantial concern (Jiang, 2014).

Both infrastructure and platform perspectives also shed light on the Google Books project.[5] Starting in 2004, Google partnered with major research universities to digitize "every" book. Google presented the project as a 21st-century update of the public and national libraries. Seen in that light, the project looked like knowledge infrastructure—and in the abstract, it could be so, opening vast new possibilities for knowledge access and discovery, including for poor and under-resourced people and regions. Yet, Google Books was immediately and tightly bound to Google's platform logic. For example, Google purchased reCAPTCHA (based on the CAPTCHA technology, that stands for Completely Automated Public Turing test to tell Computers and Humans Apart) in 2009 partly to rely on crowdsourcing to decipher characters that could not be recognized through automated optical character recognition (OCR). It also released a Google Books

API (with its attendant two-way flow of data) and allowed researchers to build applications on top of it.[6] Immediately entangled in lawsuits initiated by publishers, authors, and others, Google Books has not (yet) achieved its promise as a universal digital library; instead, other stakeholders correctly saw the project as Google's attempt to platformize the library, a major knowledge infrastructure.

As with Facebook, Google's platform logic creates real benefits for both users and third-party developers. First, in an age of government downsizing, what other organization could fund or execute such a colossal effort? Second, the ability not only to access all that knowledge but also to build upon Google's code avoids redundant effort and expense. Yet the fact remains that control of the platform puts Google in an unparalleled position of dominance, increasing its power to shape lives as well as knowledge.

As this section has shown, infrastructure studies and platform studies both make important contributions to understanding our rapidly changing networked digital landscape. Together, they help us to see the structures, the promises, and the perils of a world where (some) platforms become infrastructures, even as (many) infrastructures are being platformized. In such a world, it has become too easy to conflate the economic logics typical of platforms with the public interests and quasi-universal services formerly characteristic of many infrastructures. The question is not only who profits and controls, but who, and what, is cast aside along the way.

Conclusion

This article has examined two theoretical approaches relevant to the study of new media forms: infrastructure studies and platform studies. The constructs they address share certain notable properties, including embeddedness, a degree of invisibility, extensibility, and broad coverage. While in this manner the two theories are "joined at the hip," they are simultaneously "genetically different," emerging from different disciplinary contexts, traditionally focusing on different objects of investigation, and emphasizing different facets of their objects of study.

Through case studies of Google, Facebook, and the Open Web, we have shown that rather than distinguishing two entirely separate objects, these approaches instead offer different lenses on phenomena fundamental to everyday life in contemporary societies. We argued that an accommodation of these two lenses—a kind of theoretical bifocal—helps us to historically and critically understand how these societies are being transformed. With the rise of neoliberal economics in the 1970s came a "splintering" of the "modern infrastructural ideal" of universal service delivered by monopoly providers (Graham and Marvin, 2001). Digital technologies greatly assisted in this process, often making possible lower cost, more dynamic, and more competitive alternatives to governmental or quasi-governmental monopoly infrastructures, in exchange for a transfer of wealth and responsibility to private enterprises. The result has been what we called a "platformization of infrastructures." At the same time, the rise of platform strategies in the computer industry, and later in "Web 2.0" systems and services, made possible an "infrastructuralization of platforms." Google, Facebook, and a handful of other corporate giants have learned to exploit the power of platforms—which hold undeniable benefits for both users and smaller, independent application developers—to gain footholds as the

modern-day equivalents of the railroad, telephone, and electric utility monopolies of the late 19th and the 20th centuries.

How might scholars of these two approaches make use of our theoretical bifocal, platform-as-infrastructure, and vice versa? Certainly, they would retain the valuable historical perspective of infrastructure studies. But rather than presuppose the slow evolution and eventual stability plateau characteristic of physical, capital-intensive infrastructures, they might also take account of how rapidly "infrastructuralized platforms" have arisen in the digital age. Similarly, they might explore how information technology (IT) has helped to platformize even capital-intensive industries such as the transport of documents and goods; for example, FedEx and United Parcel Service (UPS) both grew mighty through relentless application of IT to logistics. In all cases, scholars of infrastructure could attend to the technological influences and policy alternatives that tip the delicate balance between the public interest and corporate power. It would recover the goal of comparative analysis that is often missing from some accounts of single platforms. It would recognize that the "system builders" that dominated infrastructures of the past may be replaced by "ecosystem-builders" that leverage programmability and interconnection to achieve control, rather than relying on direct provision and expansion.

We hope to foster scholarship describing conflicts or subductions between infrastructures and platforms across various sectors, possibly building on the table provided in this article. An example of such case study could be the impact of commercial platforms (such as Academia.edu or ResearchGate) on existing scholarly communication infrastructures. Another is the increasing reliance of "smart city" administration on private platforms to monitor public services and urban activity. This combined perspective, one might hope, would reassert the importance of widely available, universal, and relatively stable infrastructure as a foundation of social justice. While the private sector's constant churn of exciting new technical developments has added so much to the quality of life, its total infiltration of basic needs also imposes potentially dire political, environmental, and ethical risks.

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Notes

1. The World Wide Web Consortium itself refers to the Open Web as a "Platform." http://www.w3.org/2010/Talks/0117-next-web-plh/nextweb.html
2. https://www.netmarketshare.com/search-engine-market-share.aspx?qprid=4&qpcustomd=0
3. http://www.experian.com/marketing-services/online-trends-search-engine.html
4. http://www.nytimes.com/2015/04/16/business/international/european-union-google-antitrust-case.html?_r=0
5. https://books.google.com/
6. Examples of such applications may be found at https://developers.google.com/books/casestudies/

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