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CONTENTS

VOUCHERS

CONTENTS

VOUCHERS

CONTENTS

VOUCHERS

CONTENTS

VOUCHERS

32

SCAFFOLDING, HARD AND SOFT

Critical and Generative Infrastructures

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Everyone from tech manufacturers and app developers, to sci-fi authors and filmmakers, to real-estate developers and engineers, are conjuring up utopic visions of "sentient cities" and "quantified selves"—data-driven entities that uphold the primary virtues of efficiency and economy. Our bodies, regulated by sensors and algorithms, will become lean, high-performance machines; and our cities—ever clean and green—will respond, in real time, to our individual and collective social needs. If we dig past the enticing renderings and techno-fetishist rhetoric that characterize these plans, then we come to recognize the number of intertwined and layered networks, protocols, and practices—the interlocking *infrastructures*: smartphones, sensors, data sets, regulations, and various public and proprietary service providers—that would have to sync up perfectly for these "seamlessly" efficient digital futures to become realities. And we have to wonder about the critical issues that those connections, and potential disconnections, might raise regarding the roles that technology plays in our lives. These future data-driven scenarios—whether they are purely speculative designs or real plans for implementation—can serve us as critical tools to think with: "critical scaffolding" for analysis that, ideally, informs the way we build our future infrastructural worlds.

Infrastructure, Hard and Soft

The term "infrastructure" typically conjures up images of roads, railways, bridges, military structures, and other public works—heavily material stuff. And this is what "infrastructure" referred to when the term was first used in the mid-1920s. According to a U.S. Presidential Commission, by the late 1990s the term came to encompass "man-made systems and processes that function collaboratively and synergistically to produce and distribute a continuous flow of essential goods and services": systems like transportation, oil, gas distribution and storage, water supply, emergency management, government services, banking and finance, electrical power, and information and communications (President's Commission 1997). Yet the heavily material stuff persists even in the information age. Seemingly immaterial, ubiquitous, and placeless digital networks rely upon data centers, power plants, fiber-optic cables, satellites, mines yielding coltan and copper, and assembly-line workers and e-waste handlers regularly

exposing themselves to toxic materials (Gabrys 2011). These are among digital culture's myriad material infrastructures.

As sociologists Susan Leigh Star and Geoffrey Bowker (2006) remind us, though, intellectual and institutional structures and operations—measurement standards, technical protocols, naming conventions, bureaucratic forms, etc.—are *also* infrastructures. The scenario I painted earlier demonstrated that agreeing on, or being forced to comply with, technical protocols, measurement standards, and classification systems (all intellectual and administrative infra-structures) is necessary in order for the software and hardware to do their jobs (see Galloway 2004 for more on protocol). Star and Bowker suggest, too, that infrastructure is inevitably a flexible term, often defined with regard to context and situation. They describe infrastructure as "that which runs 'underneath' actual structures[,] . . . that upon which something else rides, or works, a platform of sorts"; but then acknowledge that "this common-sense definition begins to unravel when we . . . look at multiple, overlapping and perhaps contradictory infrastructural arrangements. For the railroad engineer, the rails are only infrastructure when she or he is a passenger" (230; see also Bowker & Star 1999: 35). In other words, infrastructure can easily flip between figure and ground.

It becomes "figure" especially when snafus occur: when that otherwise invisible platform malfunctions and calls attention to itself—as is the case when we encounter dead zones, or suffer natural disasters, or carry our locked smartphones into foreign lands, or when our devices fail to sync or operate on different frequencies, or when various stakeholders do not adhere to the same protocols, or when the legal machinery and bureaucracy codifying these stand-ards collapses under its own weight, or when government firewalls block access or corporations deem a market insufficiently lucrative to deserve a "hookup." And of course there are parts of the world where breakage and disconnection are the *norm*. And there are technicians who routinely monitor and repair cables and transformers and satellite dishes; for these people, infrastructure is commonly "figure" by default.

Infrastructure as Critical Structure: What Critical Tools and Frameworks Does a Focus on Infrastructure Offer Us?

A Deeper, Networked Media History

Even the infrastructural "ground" has its own substrate, its own platform, too. While the term infrastructure was not put into common use until the 1960s, and is thus commonly associated with modern telecommunications, the *idea* of infrastructure has existed since the dawn of civilization (see Mattern 2015). People have always needed physical, intellectual, political, and economic substrates on which to build their settlements, and those ancient structures have had residual effects across history. Digital infrastructures follow many of the same paths—the same, or very similar, conduits; similar network structure—as did early tele-communications infrastructure. "Because of the costs of developing new telecommunications networks," geographers Stephen Graham and Simon Marvin note, "all efforts are made to string optic fibers through water, gas, and sewage ducts; [and] between cities, existing railway, road, and waterway routes are often used" (1996: 329). And many early telecommunications hubs are urban centers built up over centuries in part through strength in publishing and a flourishing print culture. Cities thus become magnets for new technological development thanks to capital accumulated under old media regimes. Digital infrastructures are often predicated on their analog predecessors; old media infrastructures begat new media infra-structures.

I have written elsewhere on the deep history and temporal entanglements of urban media infrastructures—on the ways in which the rise of trade and the need for record-keeping necessarily made early human settlements into infrastructures for writing, with even the buildings' and cities' clay walls serving as substrates for written texts; and the ways in which, in the early days of democracy, cities were designed, or emerged through trial and error, to be conducive to public address and interpersonal communication (Mattern 2013a, 2015). Thinking about media infrastructure through this deep historical perspective—which requires that we borrow insights and methods from other fields, such as archaeology and urban history—helps us to recognize that media histories are entwined with the histories of our cities and civilizations, and that cities have long constituted infrastructural environments that support their essential role as communicative spaces.

The principle of "path dependency" explains how previous choices and patterns in designing and constructing systems, regardless of the circumstances or conditions under which those choices were originally made, limit our options in future developments: where the cable was lain in the past determines to some degree where we position our new conduits, which file formats have become the industry standard inform our design and production decisions, and how users have come to expect to interact with media—the habitual gestures of flipping pages and swiping screens, for instance—influences how we build familiarity and novelty into interaction design. Yet those previous "paths" are not rigidly deterministic. As Edwards et al. note, "The eventual growth of complex infrastructure and the forms it takes are the result of converging histories, path dependencies, serendipity, innovation, and 'bricolage' (tinkering)" (2007: 6–7). As we will see later, chance and human agency also have roles to play in the evolution of infrastructures and the unfolding of media and technological history.

Media Networked across Scale

Thinking about media infrastructure as networked and layered helps us to recognize that media can be embodied on a large scale—that media's modes of operation, and their aesthetics and ideologies, can be spatialized and materialized in the landscape. Today's media infrastructures encompass handheld devices and the microchips that make them work, as well as global networks and even extraterrestrial objects, like satellites, which are in turn affected by cosmic forces such as sun flares and space dust. When we think about infrastructures, then, we must also think about the granularity of our observations. Graham and Marvin list various scales of infrastructural analysis, including the corporeal, the local, the urban, the regional, the national, the international, and the global (2001: 411). Infrastructures cut across these scales and, in their role as "critical structures" or scaffolds, can even help to model "scalar thinking." Thinking at the scale of the media object (e.g., the book, the smartphone, or the modem), for instance, or the individual human-media interaction, compels us to "telescope out" and consider how those objects have been shaped across time, and how they are networked across space. Paul Edwards argues that scale need not be conceived as merely a geographic quality; it is also possible to consider scales of force (from the human body to the geophysical), scales of time (from human time to geophysical time), and scales of social organization (from individuals to governments) (2003: 186).

Expanding our unit of analysis—"scaling out" from the page, screen, or device—helps us appreciate the intermingling of various systems. For their production, distribution, and consumption, media rely on the power grid, transportation networks, waste removal systems, and even, in the case of paper production and data storage, the availability of water to power the mills and cool the server rooms. Thus, media infrastructures are inevitably part of

VOUCHERS

infrastructural "constellations" involving myriad other nonmedia-related networks. And those networks are often layered and entangled into historically "deep" systems—systems with different paths of evolution or paces of operation. Scaling *out* in scope or space thus often enables us to dig *deeply* into our networks' histories.

Virtuality's Material Scaffolding

As we have already discussed, thinking about infrastructures—particularly the fact that these networks are always *inter*-networked and mutually evolving, reinforcing, and limiting one another—also reminds us that there is a material dimension, a "heavy architecture," to even our most seemingly ephemeral and placeless (i.e., mobile or ubiquitous) media technologies. As sociologist Adrian Mackenzie argues in *Wirelessness: Radical Empiricism in Network Cultures*:

> While the notion of wireless networks implies that there are fewer wires, it could easily be argued that actually there are more wires. Rather than wireless cities or wireless networks, it might be more accurate to speak of the rewiring of cities through the highly reconfigurable paths of chipsets. Billions of chipsets means trillions of wires or conductors on a microscopic scale.
>
> (Mackenzie 2010: 64–5)

That material scaffolding scales both up and down, in and out: down to the elements mined for those chipsets and conductors; up to the systems of labor that support that mining as well as the global manufacture, distribution, and sale of gadgets; out to the networks of satellites and undersea cables as well as the governmental and corporate policies that manage and monetize them (see Parks 2005; Blum 2012; Mayer 2011; Starosielski 2015). We will inevitably find hardware and, as we will discuss below, "wetware" or biopower behind our ostensibly immaterial networks; we simply have to expand our searches—across scales, depths, and altitudes—to find it.

Human Infrastructure

Perhaps paradoxically, while we are considering the potent forces of "deep history" and path dependency, and the heavy engineering that powers our technologies, an infrastructural framework also leads us to acknowledge the role of humble human agency. People have not been mere *beneficiaries* of infrastructure; they have actually served as integral links within those infrastructural networks, providing labor for material extraction or service delivery, for instance, or filling in with their own hands when the pumps and pipes and portals fail or, as is the case in particular disenfranchised pockets of the world, when that scaffolding is simply absent. As AbdouMaliq Simone argues, today in Africa (and, we must acknowledge, in much of the Global South and throughout the history of civilization) people often compensate for "underdeveloped, overused, fragmented, and often makeshift urban infrastructures" (2004: 425). Identifying these pockets of informal or shadow infrastructural development—practices of jury-rigging, pirating, bricolaging, and kludging—highlights the inherently splintered geography of our seemingly universal infrastructures, the political economics of access, and the infrastructural roles of biopower and human agency.

Yet in thinking across the time and scale of infrastructures, attuned to the entanglement of their hard and soft scaffoldings, we create another role for individual and collective human agency: that of the engaged, critical consumer and, perhaps more important, citizen. Media

scholar Lisa Parks argues that it is our duty as infrastructural "citizen/users" to be aware of the "systems that surround [us] and that [we] subsidize and use" (2009):

> [Might we] devise . . . ways of visualizing and developing literacy about infrastructures and the relations that take shape through and around them[?] Are there ways of representing [infrastructures] that will encourage citizens to participate in sustained discussions and decisions about network ownership, development, and access?
>
> (Parks 2009)

Designers and artists have devised a number of approaches—mapping, touring, sensing, signaling, and even *playing* infrastructure—to promote infrastructural literacy (Mattern 2013b). Recent years have brought us walking tours of cell-phone antenna networks, interactive maps of transoceanic fiber-optic cables, apps leading us to the nearest public restrooms or farmer's markets, gallery exhibitions featuring photos of data centers and e-waste deposits, crowd-sourced maps of bike routes and sewage systems, and hacking and circuit-bending workshops where kids explore the guts of their iPhones. "Lines and Nodes," a Fall 2014 symposium and screening series at New York University and Anthology Film Archives examined and exhibited a variety of films, interactive projects, photo projects, and maps that make infrastructure sense-able and intelligible. All of these works promote infrastructural literacy, highlighting the value of using infrastructure as a "critical scaffolding" through which we can address important issues, including those pertaining to environmental health, the distribution of public resources, and social justice.

Many of these projects employ mapping in some form and focus on "making visible the invisible"—highlighting internet traffic, modeling data, or diagramming the "hard," material hubs and cables behind our digital infrastructures. Yet there are relatively few such projects that call attention to the human and historical dimensions of infrastructure, or that highlight the other "soft infrastructures" that Bowker and Star identify: socio-technical protocols, naming conventions, bureaucratic forms, or measurement standards. This paucity of materials to enhance *soft*-infrastructural literacy represents a great opportunity for media-makers, artists, and designers who might develop new pedagogical infrastructures for thinking *about* intellectual infrastructures. Two recent examples, however, might provide some inspiration. First, Hito Steyerl's 2013 widely exhibited and well received video, *How Not to Be Seen: A Fucking Didactic Educational .MOV File*, offers several strategies for "disappearing" oneself from surveillance technologies (I encourage you to seek out clips or stills of the video online). After addressing the protocols by which surveillance takes place, Steyerl proposes several means of evading it, some of which require a subversion of protocols or an upending of measurement standards. Those evasion techniques include camouflaging yourself, hiding in plain sight, shrinking yourself down smaller than a pixel, living in a gated community, wearing a full-body cloak, or becoming a female over 50. By referencing various marginalized populations, she undermines the position of privilege and condition of narcissism that often characterizes digital evasion strategies. Her tongue-in-cheek, yet powerfully critical, message arrives by way of a parodic form: a dark, Monty Python-esque take on the educational film—a "critical scaffolding" for thinking about soft infrastructure, with a built-in critique of established forms of instruction.

Second, Adrian Piper's *Probable Trust Registry* calls into question the ideologies scaffolded into and naturalized by our bureaucratic forms and architectures. In the gallery we find three corporate reception environments, each representing a pledge: *I will always be too expensive to buy; I will always mean what I say*; and *I will always do what I say I am going to do*. If visitors can pledge to live by these rules, they sign a contract—one copy of which is to be kept sealed

for 100 years in the Adrian Piper Research Archive in Berlin, and another copy of which goes to the signatories. At the close of the exhibition, all those who have signed pledges will receive copies of all the other signed contracts for that particular pledge. These administrative formats and processes call into question what aspects of human existence can be codified in a standardized form, what ethics might be embedded in something as seemingly "neutral" and disinterested as bureaucratic paperwork, and what protocols of privacy and access should define the archive.

Artists, media-makers, designers, critical engineers, digital humanists, and their colleagues might investigate other means of highlighting both hard *and* soft infrastructures and acknowledging their entanglement. But I propose that these critical-creative practitioners' engagement with infrastructure should extend beyond the promotion of infrastructural "awareness" and intelligence. This is not to diminish the value of such literacy, but rather to recognize designers' potential to go beyond the *representation* of infrastructure to the *design* of infrastructures themselves—more efficient, effective, accessible, intelligible, and just infrastructures. Creative practitioners, I suggest, should approach infrastructure as a generative structure—a framework for generating systems, environments, and objects and cultivating subjects and communities that embody the values we want to define our society.

Infrastructure as Generative Structure

I will close by looking at a few examples of design challenges posed by infrastructure that illustrate its relevance to and applications in various fields. First, my New School colleague, anthropologist Christina Moon, is studying the global flows of resources and labor involved in "fast fashion," a relatively new industry, emblematized by retailers such as Zara and H&M, that rapidly produces inexpensive, "disposable" garments inspired by the latest runway trends. As designers increasingly concern themselves with the ethics of labor and the sourcing of material through which their designs are *made material*, Moon's work helps us to recognize the "material intimacies" of fast fashion: the everyday social and cultural practices of designers, garment workers, and wholesalers; the potentially meaningful and constructive dimensions of their work; and the potential for transnational social ties and cultural exchange *in* that work. Rewriting and nuancing the typically pejorative ways we understand "globalization" and "neoliberalism," Moon calls designers' attention to the embodied, affective aspects of creative labor, which has the potential to inspire greater cultural and ethical sensitivity throughout the interlocking infrastructures of the global fashion industry.

Second, through their Values at Play project, Mary Flanagan and Helen Nissenbaum explore the ethics and ideologies embodied in videogame design. Among designers and the games they create, Flanagan and Nissenbaum aim to instill "positive principles" like equity, empathy, diversity, generosity, humility, and negotiation (Values at Play 2005; Flanagan & Nissenbaum 2014). They have conducted interviews with game designers and created a curriculum to encourage designers to critically reflect on the social values that *are* embodied—and perhaps *should* be embodied—in their work in various dimensions: through the game narrative, its mechanics, its interface design, and, echoing Moon's work, the labor practices and creative processes in the game industry. Again, the multiple interlocking infrastructures of gaming are considered in relation to one another, and Flanagan and Nissenbaum remind us that the values inherent in any one of those systems inform the values defining the other networks to which that system is tied.

Third, designers and critical engineers are developing new infrastructures for access to information resources in parts of the world that have thus far been un- or under-served,

or in regions subject to barriers-to-access or government or corporate surveillance, or as a response to the noted precariousness of existing networks in the midst of natural disasters and other crisis situations. As they are extolled, mesh networks—distributed systems for providing internet access—allow for greater adaptability, resilience, and sustainability and stronger privacy protections than centralized systems offered by corporate internet service providers. As Primavera De Filippi writes in *Wired*:

> What's really revolutionary about mesh networking isn't the novel use of technology. It's the fact that it provides a means for people to self-organize into communities and share resources amongst themselves: Mesh networks are operated *by the community, for the community*.
>
> (De Filippi 2014)

Indeed, the technology is not novel: the military has been using mesh networking for years to extend and secure battlefield communication in remote and rugged terrains. The infrastructural design offers affordances that appeal to highly disparate populations, and its flexibility—in geography, scale, and network structure—opens it to a variety of applications embodying widely disparate politics.

An analog counterpart to the mesh network, and our fourth example, is the Ideas Box, a portable media and information toolkit—a mobile knowledge infrastructure—designed for deployment in humanitarian crises. A collaboration among the United National Refugee Agency; designer Philippe Starck; and the nonprofit Libraries Without Borders, the project was inspired by efforts to provide victims of the 2010 Haiti earthquake with access to library resources. Each box, which was designed to conform to the size of shipping pallets (a key infrastructure for global distribution), contains tablet and laptop computers, physical books and e-books, a satellite internet connection (or technology for 3G coverage), equipment for cinema display or projection, films, board games and videogames, and materials for classes and workshops. Here we have a physical infrastructure that is designed to facilitate its deployment through global transportation networks and intended to provide an intellectual infrastructure for access to information and the cultivation of knowledge.

Fifth, returning to our discussion at the very beginning of this chapter, we should consider the potential contributions designers can make to the creation of effective, democratic, intelligible infrastructures for our imminent "sentient cities." I have written elsewhere about the need for designers to inform the way that people interact with and experience their cities' technical infrastructures or "operating systems" (Mattern 2014). In particular, I have considered how the design of "urban interfaces"—screens, installations, and gadgets that help us orient ourselves and navigate the city's various hard and soft infrastructures, track our use of various services and resources, and grant us access to urban data—could "compel us to ask questions about what kinds of cities we want, and what kind of citizens we want to be" (2014). Such an introspective design practice requires collaboration among representatives of the myriad networks that constitute a city.

> The creation of a *better* interface—an interface that reflects the ethics and politics that we want our cities to embody—is necessarily a collaborative process, one drawing on the skills of designers of all stripes, technicians, engineers, logisticians, cultural critics and theorists, artists, bus drivers and sanitation workers, politicians and political scientists, economists, policymakers and myriad others (including women and people of color, who have been egregiously underrepresented in

relevant debates). If our interfaces are to reflect and embody the values of *our* city, the conception and creation of those interfaces should be *ours*, too—not Cisco's, not the administrators', certainly not *mine* or *yours*. But ours.

(Mattern 2014)

We see a similarly holistic, ecological, cross-infrastructural approach to design reflected in the embrace of "landscape urbanism," which advocates for looking beyond architecture, or beyond individual buildings, to acknowledge that cities are composed of intertwined ecological, political-economic, technological, administrative, and social systems and processes (Waldheim 2006). Of course, cities and media objects manifest their own distinctive infrastructural entanglements, but cities and media are productively entangled, too, both in the way we study them and in the way we generate them.

Finally, I believe it is particularly important for students to consider the infrastructures undergirding and shaping their own fields of study and practice—what we might call the "cultural techniques" for making knowledge and generating work within a field. We should consider what enables a theory to take hold, a particular theorist or designer to gain prominence, a "movement" (such as landscape urbanism, the "sharing economy," or "object-oriented" philosophies) to gain traction, or a method or process to become naturalized. Underlying our theory and design economies are particular epistemological and disciplinary values, such as "innovation" and "sustainability," academic and commercial markets hungry for branded theories and methods (and even old ideas cloaked in neologisms), PR machines, and hordes of students who are eager to discover the "new big thing," which partly fuels the global networks of conferences, tech festivals, art fairs, and TED conferences (not to mention the airplanes, travel budgets, and carbon expenditures that make those gatherings possible). These are the entangled soft and hard infrastructures that often propel "making" in our fields.

In these novel movements and among the world of celebrity theorists and designers, I find that the liberal (or "leftist") conceptions of labor, knowledge, and taste *actually embodied* in their practices sometimes fail to match their professed politics. We are so frequently advocating for more democratic, fluid, inclusive, and ethical models of making and thinking in the world, yet the theories and practices we are building to make sense of these new modes are still often *built* via "Great Man" modes of production.

Even young critical thinkers and makers in media and design have the capacity, perhaps even the obligation, to map, deeply and widely, the infrastructures—the cultural techniques—that undergird the work in their fields, particularly the work on the "bleeding edge." Recognizing the entwined infrastructures that constitute this substrate for practice will ideally cultivate a sensitivity to issues of access, diversity, inclusivity, authorship, attribution, epistemology, and other social values and ethical concerns. Recognizing what is missing in one's field's *current* infrastructural ecology might inspire him or her to contribute to the design of a discursive space or landscape of practice that embodies a political economy more in line with those social values that our theories espouse. You, as critical-creative practitioners, have the opportunity to transform criticality into generativity—to *imagine* and *construct* the hard and soft scaffoldings for tomorrow's fields of practice.

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VOUCHERS

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