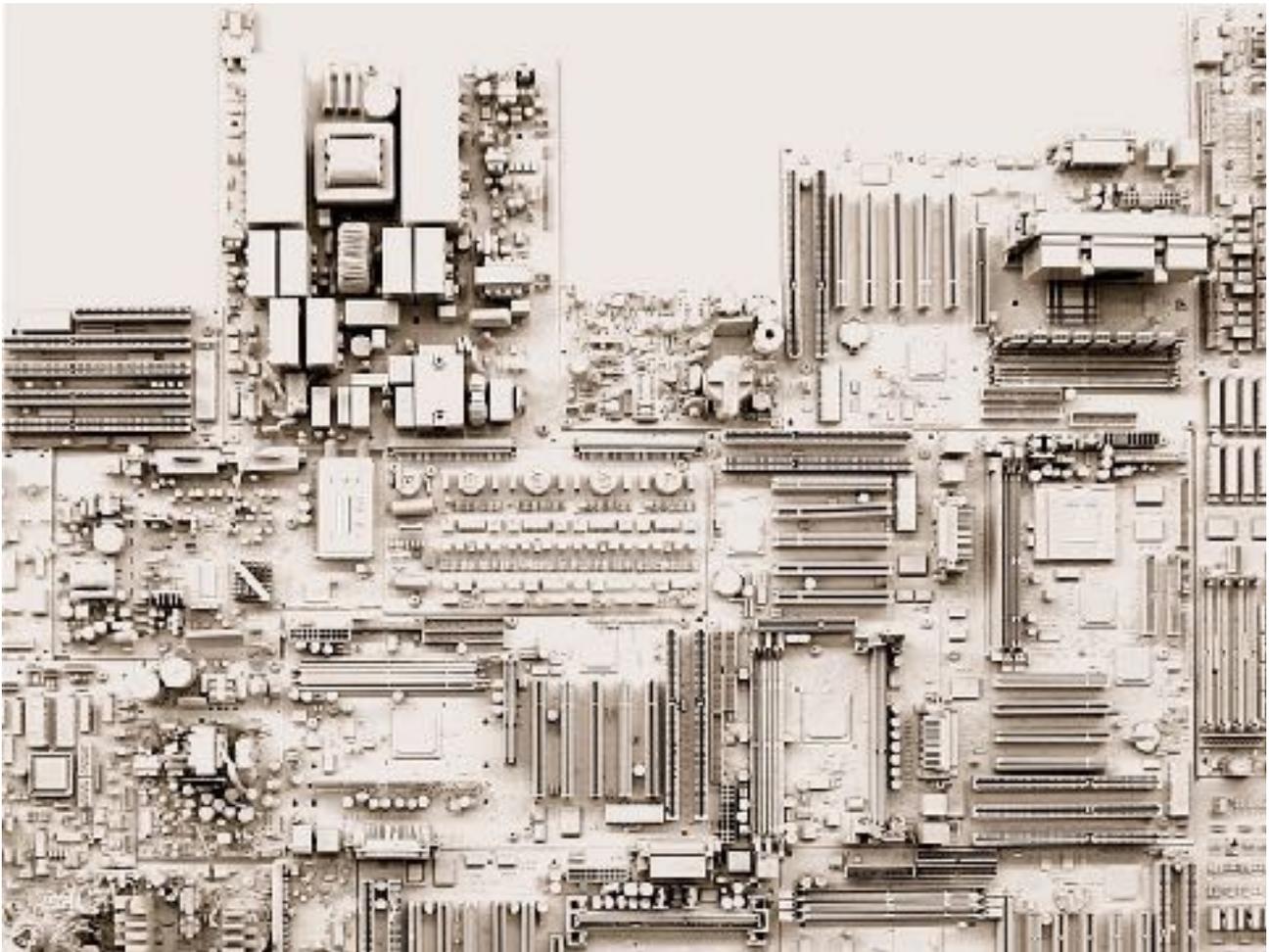## A City Is Not a Computer

This seems an obvious truth, but we need to say it loud and clear. Urban intelligence is more than information processing.

SHANNON MATTERN
FEBRUARY 2017

https://placesjournal.org/article/a-city-is-not-a-computer/?
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utm_campaign=buffer

A wall in Bairro Alto, Lisbon, covered with circuit boards painted white.
[Daniel Gonçalves]

"What should a city optimize for?" Even in the age of peak Silicon Valley, that's a hard question to take seriously. (Hecklers on Twitter had a few ideas, like "fish tacos" and "pez dispensers.") 1 Look past the sarcasm, though, and you'll find an ideology on the rise. The question was posed last summer by Y Combinator — the formidable tech accelerator that has hatched a thousand startups, from AirBnB and Dropbox to robotic greenhouses and wine-by-the-glass delivery — as the entrepreneurs announced a new

research agenda: building cities from scratch. Wired's verdict: "Not Actually Crazy." 2

Which is not to say wise. For every reasonable question Y Combinator asked — "How can cities help more of their residents be happy and reach their potential?" — there was a preposterous one: "How should we measure the effectiveness of a city (what are its KPIs)?" That's Key Performance Indicators, for those not steeped in business intelligence jargon. There was hardly any mention of the urban designers, planners, and scholars who have been asking the big questions for centuries: How do cities function, and how can they function better?

Tech companies have come out forcefully against the Muslim travel ban, but where will they stand on subtler questions of social 'optimization'?

Of course, it's possible that no city will be harmed in the making of this research. Half a year later, the public output of the New Cities project consists of two blog posts, one announcing the program and the other reporting the first hire. Still, the rhetoric deserves close attention, because, frankly, in this new political age, all rhetoric demands scrutiny. At the highest levels of government, we see evidence and quantitative data manipulated or manufactured to justify reckless orders, disrupting not only "politics as usual," but also fundamental democratic principles. Much of the work in urban tech has the potential to play right into this new mode of governance. Tech companies have come out forcefully against the Muslim travel ban, but where will they stand on subtler questions of social "optimization"? Autonomous vehicles and pervasive cameras and sensors are just the sort of disruptive technologies that an infrastructure-championing president might deem "tremendous." Donald Trump's chief strategist (who, years ago, ran the Biosphere 2 experiment into the ground) is also on the board of a data mining and analytics firm that seeks government contracts. Will the president start tweeting about how crime-ridden (and racialized) "inner cities" would be a whole lot better if they were run like computers?

It's a politically complicated environment, to say the least. Into the ring steps the first hire at New Cities: Ben Huh, founder of the meme-and-cat-pic empire Cheezburger. "There's no shortage of space to build new cities," he effervesced, in a post explaining his decision to join the Y Combinator project. "Technology can seed fertile starting conditions across nations and geographies." His goal for the six-month research position: to "create an open, repeatable system for rapid cityforming that maximize[s] human potential." 3 No pressure.

Parkour in Al-Azhar Park, Cairo. [Nasser Nouri]

Queer dance party outside the Republican congressional retreat in Philadelphia last month. [Joe Piette]

Cicloruta in Mérida, Mexico. [Ian Morton]

Meanwhile, Alphabet (née Google) is moving forward with plans to build its own optimized cities. Its urban-tech division, Sidewalk Labs, has already installed public WiFi kiosks on New York City streets: infrastructural nodes (known as "Links") that may someday exchange data with autonomous vehicles, public transit, and other urban systems. 4 The company is also partnering with the U.S. Department of Transportation on efforts like the "Smart City Challenge," which awarded a $50 million grant to Columbus, Ohio. Last June, on the same day Y Combinator announced its New Cities project, The Guardian published details of Alphabet's "Flow," the cloud software behind the mobility experiments in Columbus. 5 Within months, partnerships were underway in 16 other cities. 6

As everyone was watching the drama at Trump Tower, Google was betting on a 'fourth revolution' in urban infrastructure.

Urban transportation is the first target for disruption, but it won't end there. Dan Doctoroff, the Michael Bloomberg associate who founded Sidewalk Labs, wonders, "What would a city look like if you started from scratch in the internet era—if you built a city 'from the internet up?'" In November, the company took another step in that direction, launching four new "labs" that will work on housing affordability, health care and social services, municipal processes, and community collaboration. The company plans to run pilot

projects in select urban districts, then scale up. Announcing the expansion, Doctoroff recalled past "revolutions" in urban technologies:

Looking at history, one can make the argument that the greatest periods of economic growth and productivity have occurred when we have integrated innovation into the physical environment, especially in cities. The steam engine, electricity grid, and automobile all fundamentally transformed urban life, but we haven't really seen much change in our cities since before World War II. If you compare pictures of cities from 1870 to 1940, it's like night and day. If you make the same comparison from 1940 to today, hardly anything has changed. Thus it's not surprising that, despite the rise of computers and the internet, growth has slowed and productivity increases are so low. … So our mission is to accelerate the process of urban innovation. 7

While Doctoroff has been telling some version of this story since Sidewalk Labs launched in 2015, the timing of the new expansion, three weeks after the U.S. presidential election, alters the context. As everyone was watching the drama at Trump Tower, the world's largest searching-mapping-driving-advertising-information-organizing company was throwing its resources behind a "fourth revolution" in urban infrastructure.
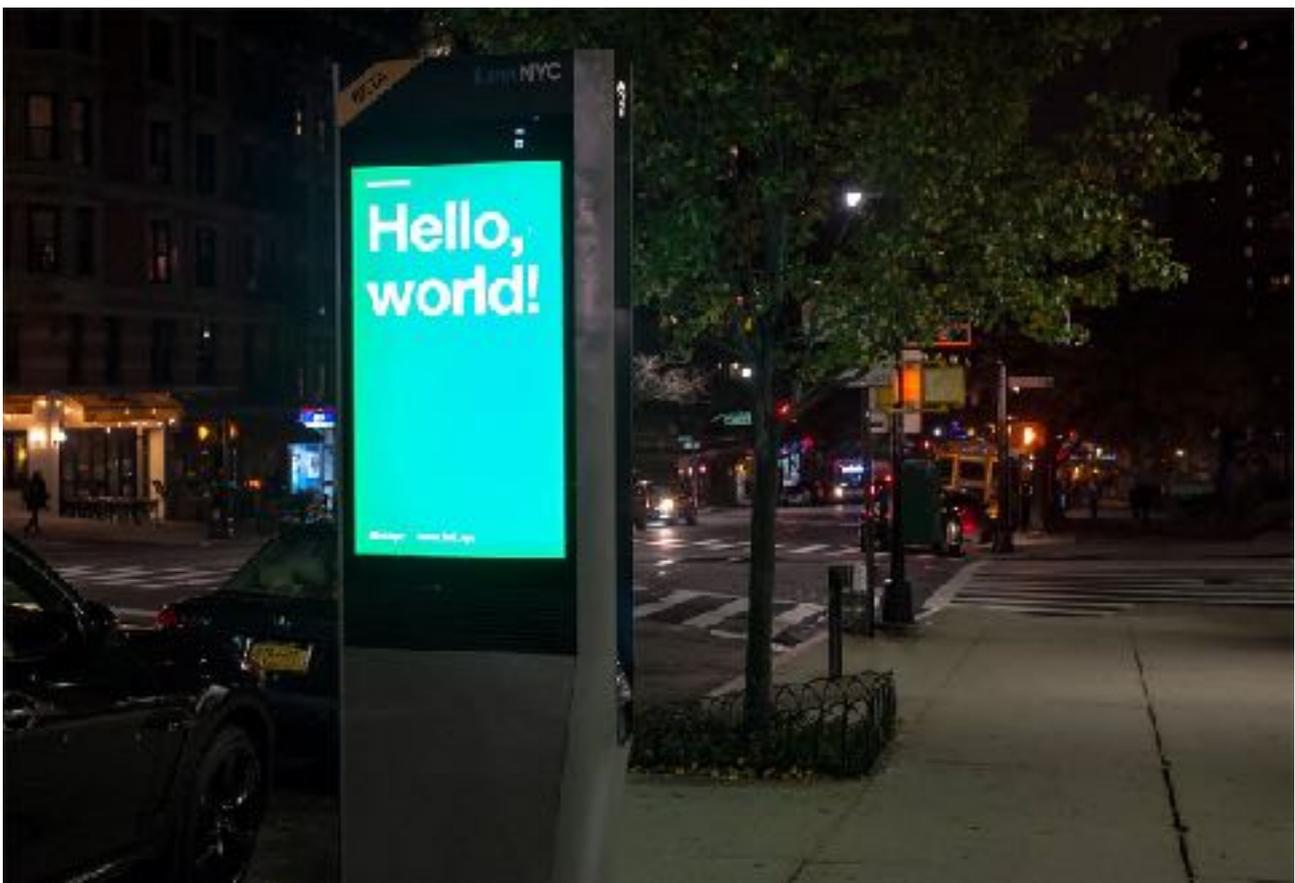
A LinkNYC kiosk greets New Yorkers on November 15, 2016. [Billie Grace Ward]

Dreams of an Informatic Urbanism

Of course, major companies like Alphabet have already dramatically reshaped the cities where they are headquartered, 8 but they have not yet had the luxury of building on a blank slate. The idea of the "new city" certainly isn't new, and the model now emerging in the United States has precedents in Asian and Middle Eastern countries, where Cisco, Siemens, and IBM have partnered with real-estate developers and governments to build "smart cities" tabula rasa.

We don't know how these urban experiments will fare. Since they are in a constant state of development, always "versioning" toward an optimized model ever on the horizon, they are not easily evaluated or critiqued. 9 If you believe the marketing hype, though, we're on the cusp of an urban future in which embedded sensors, ubiquitous cameras and beacons, networked smartphones, and the operating systems that link them all together, will produce unprecedented efficiency, connectivity, and social harmony. We're transforming the idealized topology of the open web and Internet of Things into urban form.

Programmer and tech writer Paul McFedries explains this thinking:

The city is a computer, the streetscape is the interface, you are the cursor, and your smartphone is the input device. This is the user-based, bottom-up version of the city-as-computer idea, but there's also a top-down version, which is systems-based. It looks at urban systems such as transit, garbage, and water and wonders whether the city could be more efficient and better organized if these systems were 'smart.' 10

While projects like Sidewalk Labs and Y Combinator's New Cities were conceived in an age of big data and cloud computing, they are rooted in earlier reveries. Ever since the internet was little more than a few linked nodes, urbanists, technologists, and sci-fi writers have envisioned cybercities and e-topias built "from the 'net up.'" 11 Modernist designers and futurists saw morphological parallels between urban forms and circuit boards. Just as new modes of telecommunication have always reshaped physical terrains and political economies, new computational methods have informed urban planning, modeling, and administration. 12

Our current paradigm, the city as computer, appeals because it frames the messiness of urban life as programmable and subject to rational order. Modernity is good at renewing metaphors, from the city as machine, to the city as organism or ecology, to the city as cyborgian merger of the technological and the organic. 13 Our current paradigm, the city as computer, appeals because it frames the messiness of urban life as programmable and subject to rational order. Anthropologist Hannah Knox explains, "As technical solutions to social problems, information and communications technologies encapsulate the promise of order over disarray … as a path to an emancipatory politics of modernity." 14 And there are echoes of the pre-modern, too. The computational city draws power

from an urban imaginary that goes back millennia, to the city as an apparatus for record-keeping and information management.

We've long conceived of our cities as knowledge repositories and data processors, and they've always functioned as such. Lewis Mumford observed that when the wandering rulers of the European Middle Ages settled in capital cities, they installed a "regiment of clerks and permanent officials" and established all manner of paperwork and policies (deeds, tax records, passports, fines, regulations), which necessitated a new urban apparatus, the office building, to house its bureaus and bureaucracy. 15 The classic example is the Uffizi (Offices) in Florence, designed by Giorgio Vasari in the mid-16th century, which provided an architectural template copied in cities around the world. "The repetitions and regimentations of the bureaucratic system" — the work of data processing, formatting, and storage — left a "deep mark," as Mumford put it, on the early modern city. 16

U.S. Postal Service delivery boxes on a street corner in lower Manhattan. [Chad Carpenter]

Yet the city's informational role began even earlier than that. Writing and urbanization developed concurrently in the ancient world, and those early scripts — on clay tablets, mud-brick walls, and landforms of various types — were used to record transactions, mark territory, celebrate ritual, and embed contextual information in landscape. 17 Mumford described the city as a fundamentally communicative space, rich in information:

Through its concentration of physical and cultural power, the city heightened the tempo of human intercourse and translated its products into forms that could be stored and reproduced. Through its monuments, written records, and orderly habits of association, the city enlarged the scope of all human activities, extending them backwards and forwards in time. By means of its storage facilities (buildings, vaults, archives, monuments, tablets, books), the city became capable of transmitting a complex culture from generation to generation, for it marshaled together not only the physical means but the human agents needed to pass on and enlarge this heritage. That remains the greatest of the city's gifts. As compared with the complex human order of the city, our present ingenious electronic mechanisms for storing and transmitting information are crude and limited. 18

Mumford's city is an assemblage of media forms (vaults, archives, monuments, physical and electronic records, oral histories, lived cultural heritage); agents (architectures, institutions, media technologies, people); and functions (storage, processing, transmission, reproduction, contextualization, operationalization). 19 It is a large, complex, and varied epistemological and bureaucratic apparatus. It is an information processor, to be sure, but it is also more than that.

Lewis Mumford described the city as a fundamentally communicative space, rich in information. He would reject the creeping notion that the city is simply the internet writ large.

Were he alive today, Mumford would reject the creeping notion that the city is simply the internet writ large. He would remind us that the processes of city-making are more complicated than writing parameters for rapid spatial optimization. He would inject history and happenstance. The city is not a computer. This seems an obvious truth, but it is being challenged now (again) by technologists (and political actors) who speak as if they could reduce urban planning to algorithms. 20

Why should we care about debunking obviously false metaphors? It matters because the metaphors give rise to technical models, which inform design processes, which in turn shape knowledges and politics, not to mention material cities. The sites and systems where we locate the city's informational functions — the places where we see information-processing, storage, and transmission "happening" in the urban landscape — shape larger understandings of urban intelligence.

City Light Power Control Center, Seattle, 1968. [Seattle Municipal Archives]

Informational Ecologies of the City

The idea of the city as an information-processing machine has in recent years manifested as a cultural obsession with urban sites of data storage and transmission. Scholars, artists, and designers write books, conduct walking tours, and make maps of internet infrastructures. We take pleasure in pointing at nondescript buildings that hold thousands of whirring servers, at surveillance cameras, camouflaged antennae, and hovering drones. We declare: "the city's computation happens here." 21

There is more than information processing going on here. Urban information is made, commodified, accessed, secreted, politicized, and operationalized. Yet such work runs the risk of reifying and essentializing information, even depoliticizing it. When we treat data as a "given" (which is, in fact, the etymology of the word), we see it in the abstract, as an urban fixture like traffic or crowds. We need to shift our gaze and look at data in context, at the lifecycle of urban information, distributed within a varied ecology of urban sites and subjects who interact with it in multiple ways. We need to see data's human, institutional, and technological creators, its curators, its preservers, its owners and brokers, its "users," its hackers and critics. As Mumford understood, there is more than information processing going on here. Urban information is made, commodified, accessed, secreted, politicized, and operationalized.

But where? Can we point to the chips and drives, cables and warehouses — the specific urban architectures and infrastructures — where this expanded ecology of information management resides and operates? I've written about the challenges of reducing complicated technical and intellectual structures to their material, geographic manifestations, i.e., mapping "where the data live." 22 Yet such exercises can be useful in identifying points of entry to the larger system. It's not only the infrastructural object that matters; it's also the personnel and paperwork and protocols, the machines and management practices, the conduits and cultural variables that shape terrain within the larger ecology of urban information.

Street art in Rio de Janeiro. [Paul Keller]

So the next time you're staring up at a Domain Awareness camera, ask how it got there, how it generates data — not only how the equipment operates technically, but also what information it claims to be harvesting, and through what methodology — and whose interests it serves. And don't let the totalizing idea of the city as computer blind you to the countless other forms of data and sites of intelligence-generation in the city: municipal agencies and departments, universities, hospitals, laboratories, corporations. Each of these sites has a distinctive orientation toward urban intelligence. Let us consider a few of the more public ones.

Don't let the totalizing idea of the city as computer blind you to the countless other forms of data and sites of intelligence-generation.

First, the municipal archive. Most cities today have archives that contains records of administrative activity, finances, land ownership and taxes, legislation and labor. The archives of ancient Mesopotamian and Egyptian

cities held similar material, although historians debate whether ancient record-keeping practices served similar documentary functions. 23 Archives ensure financial accountability, symbolically legitimize governing bodies and colonial rulers, and erase the heritage of previous regimes and conquered populations. They monumentalize a culture's historical consciousness and intellectual riches. In the modern age, they also support scholarship. 24 Thus, the "information" inherent in the archive resides not solely in the content of its documents, but also in their very existence, their provenance and organization (there's much to be learned about the ideals of a culture by examining its archival forms), and even in the archive's omissions and erasures. 25

Archival photo of the Barrikady Gun Factory, Stalingrad, ca. 1942.

Of course, not all archives are ideologically equal. Community archives validate the personal histories and intellectual contributions of diverse publics. Meanwhile, law enforcement agencies and customs and immigration offices are networked with geographically distributed National Security Agency repositories and other federal black boxes. These archives are not of the same species, nor do they "process" "data" in the same fashion. Practices and politics of curation and access have historically distinguished archives from another key site of urban information: libraries. Whereas archives collect unpublished materials and attend primarily to their preservation and security, libraries collect published materials and aim to make them intelligible and accessible to patrons. In practice, such

distinctions are fuzzy and contested, especially today, as many archives seek to be more public-facing. Nevertheless, these two institutions embody different knowledge regimes and ideologies.

Modern libraries and librarians have sought to empower patrons to access information across platforms and formats, and to critically assess bias, privacy, and other issues under the rubric of "information literacy." 26 They build a critical framework around their resources, often in partnership with schools and universities. Further, libraries perform vital symbolic functions, embodying the city's commitment to its intellectual heritage (which may include heritage commandeered through imperial activities).

Similarly, the city's museums reflect its commitment to knowledge in embodied form, to its artifacts and material culture. Again, such institutions are open to ideological critique. Acquisition policies, display practices, and access protocols are immediate and tangible, and they reflect particular cultural and intellectual politics.

Urban intervention at the Venice Biennale, 2015. [Régine Debatty]

Just as important as the data stored and accessed on city servers, in archival boxes, on library shelves and museum walls are the forms of urban intelligence that cannot be easily contained, framed, and catalogued. We need to ask: What place-based "information" doesn't fit on a shelf or in a database? What are the non-textual, un-recordable forms of cultural memory? These questions are especially relevant for marginalized

populations, indigenous cultures, and developing nations. Performance studies scholar Diana Taylor urges us to acknowledge ephemeral, performative forms of knowledge, such as dance, ritual, cooking, sports, and speech. 27 These forms cannot be reduced to "information," nor can they be "processed," stored, or transmitted via fiber-optic cable. Yet they are vital urban intelligences that live within bodies, minds, and communities.

What forms of cultural memory don't fit on library shelves or city servers? Performative knowledge like dance, ritual, cooking, sports. Ambient data like shadows, wind, and rust.

Finally, consider data of the environmental, ambient, "immanent" kind. Malcolm McCullough has shown that our cities are full of fixed architectures, persistent terrains, and reliable environmental patterns that anchor all the unstructured data and image streams that float on top. 28 What can we learn from the "nonsemantic information" inherent in shadows, wind, rust, in the signs of wear on a well-trodden staircase, the creaks of a battered bridge — all the indexical messages of our material environments? I'd argue that the intellectual value of this ambient, immanent information exceeds its function as stable ground for the city's digital flux. Environmental data are just as much figure as they are ground. They remind us of necessary truths: that urban intelligence comes in multiple forms, that it is produced within environmental as well as cultural contexts, that it is reshaped over the longue durée by elemental exposure and urban development, that it can be lost or forgotten. These data remind us to think on a climatic scale, a geologic scale, as opposed to the scale of financial markets, transit patterns, and news cycles.

Mill Ruins Park, Minneapolis. [Flickr/Commons]

The Case Against "Information Processing"

Here's some geologic insight from T. S. Eliot's 1934 poem "The Rock":

Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in the information?

Management theorist Russell Ackoff took Eliot's idea one step further, proposing the now famous (and widely debated) hierarchy: Data < Information < Knowledge < Wisdom. 29 Each level of processing implies an extraction of utility from the level before. Thus, contextualized or patterned data can be called information. Or, to quote philosopher and computer scientist Frederick Thompson, information is "a product that results from applying the processes of organization to the raw material of experience, much like steel is obtained from iron ore." Swapping the industrial metaphor for an artistic one, he writes, "data are to the scientist like the colors on the palette of the painter. It is by the artistry of his theories that we are informed. It is the organization that is the information." 30 Thompson's mixed metaphors suggest that there are multiple ways of turning data into information and knowledge into wisdom.

Urban intelligence involves experience, observation, sensory engagement. We need new models for thinking about cities that do not compute.

Yet the term "information processing," whether employed within computer science, cognitive psychology, or urban design, typically refers to computational methods. As Riccardo Manzotti explains, when neuroscientists adopt the metaphor of the brain as computer, they imply that information is "stuff" that's mentally "processed," which they know is not true in any real sense. The metaphor survives because it makes an irresistible claim about "how marvelously complex we are and how clever scientists have become." 31 Psychologist Robert Epstein laments that "some of the world's most influential thinkers have made grand predictions about humanity's future that depend on the validity of the metaphor." 32 But the appeal of analogy is nothing new. Throughout history, the brain (like the city) has been subjected to bad metaphors derived from the technologies of the time. According to Epstein, we've imagined ourselves as lumps of clay infused with spirits, as hydraulic or electro-chemical systems, as automata. The brain as computer is just the latest link in a long chain of metaphors that powerfully shape scientific endeavor in their own images.

The city as computer model likewise conditions urban design, planning, policy, and administration — even residents' everyday experience — in ways that hinder the development of healthy, just, and resilient cities. Let's apply Manzotti's and Epstein's critiques at the city scale. We have seen that urban ecologies "process" data by means that are not strictly algorithmic, and that not all urban intelligences can be called "information." One can't "process" the local cultural effects of long-term weather patterns or derive insights from the generational evolution of a neighborhood without a degree of

sensitivity that exceeds mere computation. Urban intelligence of this kind involves site-based experience, participant observation, sensory engagement. We need new models for thinking about cities that do not compute, and we need new terminology. In contemporary urban discourses, where "data" rhetoric is often frothy and fetishistic, we seem to have lost critical perspective on how urban data become meaningful spatial information or translate into place-based knowledge.

Kids playing handball at Le Corbusier's Open Hand Monument in Chandigarh, India. [Lian Chang]

We need to expand our repertoire (to borrow a term from Diana Taylor) of urban intelligences, to draw upon the wisdom of information scientists and theorists, archivists, librarians, intellectual historians, cognitive scientists, philosophers, and others who think about the management of information and the production of knowledge. 33 They can help us better understand the breadth of intelligences that are integrated within our cities, which would be greatly impoverished if they were to be rebuilt, or built anew, with computational logic as their prevailing epistemology.
We could also be better attuned to the lifecycles of urban information resources — to their creation, curation, provision, preservation, and destruction — and to the assemblages of urban sites and subjects that make up our cities' intellectual ecologies. "If we think of the city as a long-term construct, with more complex behaviors and processes of formation, feedback, and processing," architect Tom Verebes proposes, then we can

imagine it as an organization, or even an organism, that can learn. 34
Urbanists and designers are already drawing on concepts and methods from
artificial intelligence research: neural nets, cellular processes, evolutionary
algorithms, mutation and evolution. 35 Perhaps quantum entanglement and
other computer science breakthroughs could reshape the way we think
about urban information, too. Yet we must be cautious to avoid translating
this interdisciplinary intelligence into a new urban formalism.
We should reject data-driven models that delegate critical, often ethical
decisions to the machine.
Instead of more gratuitous parametric modeling, we need to think about
urban epistemologies that embrace memory and history; that recognize
spatial intelligence as sensory and experiential; that consider other species'
ways of knowing; that appreciate the wisdom of local crowds and
communities; that acknowledge the information embedded in the city's
facades, flora, statuary, and stairways; that aim to integrate forms of
distributed cognition paralleling our brains' own distributed cognitive
processes.
We must also recognize the shortcomings in models that presume the
objectivity of urban data and conveniently delegate critical, often ethical
decisions to the machine. We, humans, make urban information by various
means: through sensory experience, through long-term exposure to a place,
and, yes, by systematically filtering data. It's essential to make space in our
cities for those diverse methods of knowledge production. And we have to
grapple with the political and ethical implications of our methods and
models, embedded in all acts of planning and design. City-making is always,
simultaneously, an enactment of city-knowing — which cannot be reduced
to computation.

Notes

1   Adora Cheung and Sam Altman, "New Cities," Y Combinator Blog,
    June 27, 2016. The post drew responses on Twitter from designer and
    urbanist Fred Scharmen ("fish tacos") and visual journalist Erik Reyna
    ("pez dispensers"), among others. ↵
2   Margaret Rhodes, "Y Combinator's Plan to Build a New City? Not
    Actually Crazy," Wired, July 8, 2016. ↵
3   Ben Huh, "Should I Pursue My Passion or Business?," Medium,
    October 25, 2016. ↵
4   Sidewalk Labs is a key investor in Intersection, the "municipal media
    company" that is a partner in LinkNYC. See Shannon
    Mattern,"Instrumental City: The View from Hudson Yards, Circa 2019,"
    Places Journal, April 2016, https://doi.org/10.22269/160426; Eliot
    Brown, "Alphabet's Next Big Thing: Building a 'Smart' City," Wall Street
    Journal, April 27, 2016; Jessica E. Lessin, "Alphabet's Sidewalk Preps
    Proposal for Digital District," The Information, April 14, 2016; Cory

Weinberg, "Is Alphabet Going to Build a City," The Information, April 5, 2016. ↵

5   Mark Harris, "Secretive Alphabet Division Funded by Google Aims to Fix Public Transit in US," The Guardian, June 27, 2016. ↵

6   Transportation for America, press release, "16 Cities Join T4America's Smart Cities Collaborative to Tackle Urban Mobility Challenges Together," October 18, 2016. ↵

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8   See Susie Cagle, "Why One Silicon Valley City Said 'No' to Google," Next City, May 11, 2015; Sean Hollister, "Welcome to Googletown," The Verge, February 26, 2014; Chris Morris-Lent, "How Amazon Swallowed Seattle," Gawker, August 18, 2015. ↵

9   Orit Halpern and Robert Mitchell, "The Smartness Mandate: Notes Toward a Critique," Grey Room (forthcoming). ↵

10 Paul McFedries, "The City as System [Technically Speaking]," IEEE Spectrum 51:4 (April 2014): 36, https://doi.org/10.1109/MSPEC. 2014.6776302. ↵

11 M. Christine Boyer, CyberCities: Visual Perception in the Age of Electronic Communication (New York: Princeton Architectural Press, 1996); Manuel Castells, The Informational City: Information Technology, Economic Restructuring, and the Urban-Regional Process (Oxford: Basel Blackwell, 1989); William Gibson, Neuromancer (New York: Ace Books, 1984); William J. Mitchell, City of Bits: Space, Place, and the Infobahn (Cambridge: MIT Press, 1995); William J. Mitchell, e-topia: Urban Life, Jim – But Not as We Know It (Cambridge: MIT Press, 2000). ↵

12 Stephen Graham and Simon Marvin, Telecommunications and the City: Electronic Spaces, Urban Places (New York: Routledge, 1996); Jennifer Light, From Warfare to Welfare: Defense Intellectuals and Urban Problems in Cold War America (Baltimore: Johns Hopkins University Press, 2004); Mark Vallianatos, "Uncovering the Early History of 'Big Data' and 'Smart City' in Los Angeles," Boom California (June 2015). ↵

13 Some argue that the city-as-machine has a much deeper history, as evidenced by use of grid layouts, linear patterns, and regular geometric forms since ancient times, and by the use of standardized patterns for colonial urban development. See, for instance, Kevin Lynch, Good City Form (Cambridge: MIT Press, 1981): 81-88. See also Matthew Gandy, "Cyborg Urbanization: Complexity and Monstrosity in the Contemporary City," International Journal of Urban and Regional Research 29: (March 2005): 26-49, https://doi.org/10.1111/j. 1468-2427.2005.00568.x; Peter Nientied, "Metaphor and Urban Studies: A Crossover, Theory and a Case Study of SS Rotterdam,"

City, Territory and Architecture 3:21 (2016), https://doi.org/10.1186/s40410-016-0051-z; William Solesbury, "How Metaphors Help Us Understand Cities," Geography 99:3 (Autumn 2014): 139-42; Tom Verebes, "The Interactive Urban Model: Histories and Legacies Related to Prototyping the Twenty-First Century City," Frontiers in Digital Humanities 3 (February 2016), https://doi.org/10.3389/fdigh.2016.00001. ↵

14 Hannah Knox, "Cities and Organisation: The Information City and Urban Form," Culture and Organization 16:3 (September 2010): 187-8, https://doi.org/10.1080/14759551.2010.503496. ↵

15 Lewis Mumford, The City in History: Its Origins, Its Transformations, and Its Prospects (New York: Harcourt, 1961): 344. ↵

16 See also Friedrich A. Kittler, "The City Is a Medium," New Literary History 27:4 (1996): 721-2, https://doi.org/10.1353/nlh.1996.0051. ↵

17 Shannon Mattern, "Of Mud, Media, and the Metropolis: Aggregating Histories of Writing and Urbanization," Cultural Politics 12:3 (November 2016): 310-31, https://10.1215/17432197-3648870. ↵

18 Mumford, 569. ↵

19 Marcus Foth's conception of "urban informatics" is similarly capacious: it encompasses "the collection, classification, storage, retrieval, and dissemination of recorded knowledge," either (1) in a city or (2) "of, relating to, characteristic of, or constituting a city." See Foth, Ed. Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City (Hershey, PA: Information Science Reference, 2009), xxiii. Such a definition acknowledges a wide variety of informational functions, contents, and contexts. Yet his focus on recorded knowledge, and on informatics' reputation as a "science" of data processing, still limit our understanding of the city's epistemological functions. ↵

20 For more on the algorithm as a timely conceptual model, see Massimo Mazzotti, "Algorithmic Life," Los Angeles Review of Books, January 22, 2017. ↵

21 For a survey of this work, see Shannon Mattern, "Cloud and Field," Places Journal, August 2016, https://doi.org/10.22269/160802, and Shannon Mattern, "Infastructural Tourism," Places Journal, July 2013, https://doi.org/10.22269/130701. For prominent examples, see Andrew Blum, Tubes: A Journey to the Center of the Internet (New York: HarperCollins, 2012), and the work of Ingrid Burrington and Mél Hogan. ↵

22 Mattern, "Cloud and Field," op. cit. See also Louise Amoore, "Cloud Geographies: Computing, Data, Sovereignty," Progress in Human Geography, August 2016, https://doi.org/10.1177/0309132516662147. ↵

23 James J. O'Toole, "Back to the Future: Ernst Posner's Archives in the Ancient World," The American Archivist 67 (Fall/Winter 2004): 161-75, https://doi.org/10.17723/aarc.67.2.h124276213041315. ↵

24 Alexandra Walsham, "The Social History of the Archive: Record-Keeping in Early Modern Europe," Past & Present 230, Issue Supplement 11 (2016): 9-48, https://doi.org/10.1093/pastj/gtw033. ↵

25 Ann Stoler, Against the Archival Grain: Epistemic Anxieties and Colonial Common Sense (Princeton: Princeton University Press, 2010). ↵

26 Shannon Mattern, "Public In/Formation," Places Journal, November 2016, https://doi.org/10.22269/161115. ↵

27 Diana Taylor, The Archive and the Repertoire: Performing Cultural Memory in the Americas (Durham, NC: Duke University Press, 2003). ↵

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