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Implementing Digital Infrastructure Responses to Equity, Sustainability, and Safety

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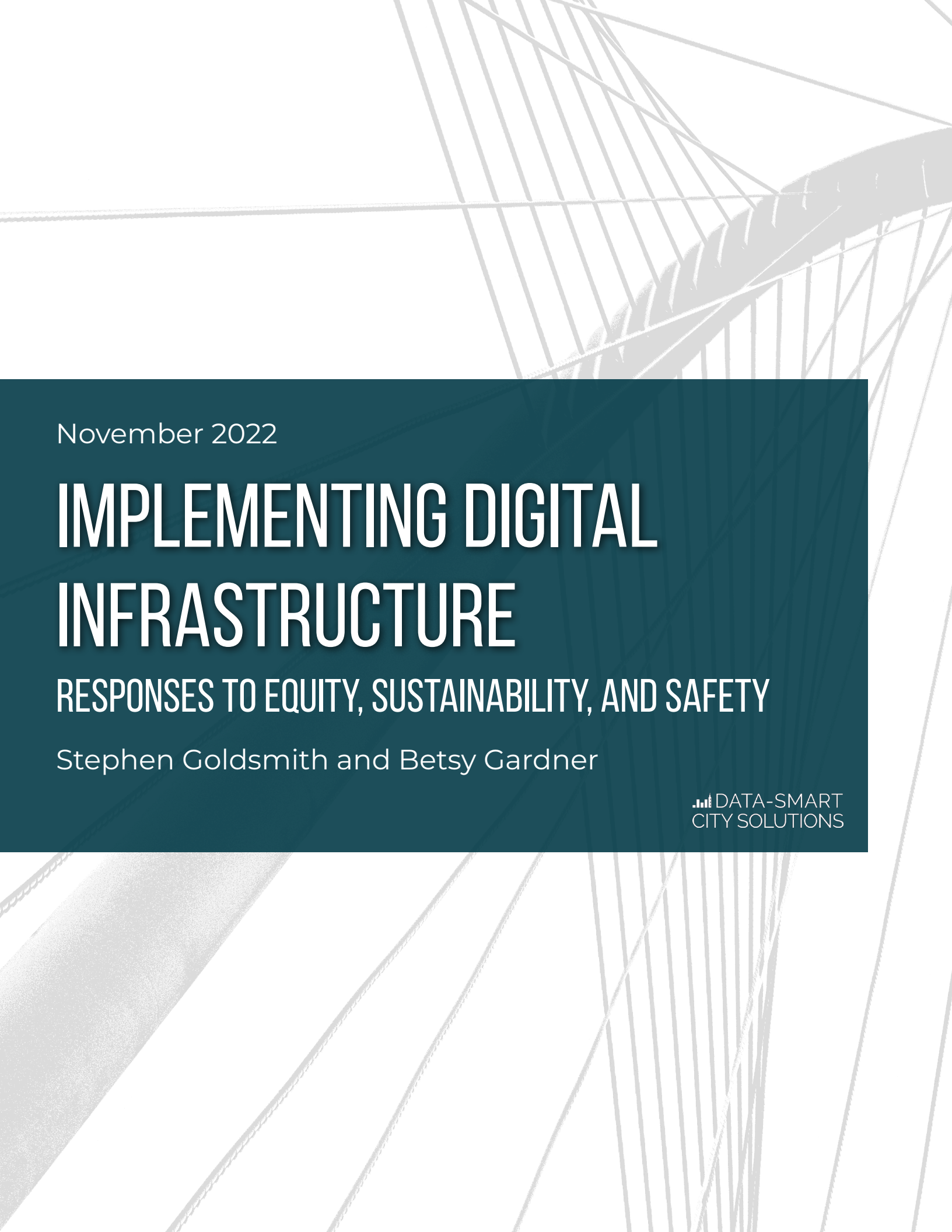
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November 2022

IMPLEMENTING DIGITAL INFRASTRUCTURE

RESPONSES TO EQUITY, SUSTAINABILITY, AND SAFETY

Stephen Goldsmith and Betsy Gardner

DATA-SMART CITY SOLUTIONS

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About the Authors

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About Data-Smart City Solutions

Data-Smart City Solutions is working to catalyze adoption of data projects on the local government level by serving as a central resource for cities interested in this emerging field. We highlight best practices, top innovators, and promising case studies while also connecting leading industry, academic, and government officials. Our research focus is the intersection of government and data, ranging from open data and predictive analytics to civic engagement technology. We seek to promote the combination of integrated, cross-agency data with community data to better discover and preemptively address civic problems. Our website, datasmart.ash.harvard.edu, and our broader work are housed at the Bloomberg Center for Cities at Harvard University.

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This paper was sparked by our Working Group for Digital Infrastructure, Equity, and Sustainability, which met on June 23, 2022, in Washington, DC. Supported by the John S. and James L. Knight Foundation, the working group convened key city officials from across the US for peer exchange and learning about policy, data, and intelligent infrastructure. The meeting featured speakers from the White House, the private sector, leading national universities and research institutions, and the nonprofit sector.

IMPLEMENTING DIGITAL INFRASTRUCTURE RESPONSES TO EQUITY, SUSTAINABILITY AND SAFETY

Executive Summary

Local leaders across the United States have a unique opportunity to address crumbling infrastructure and increasing inequities thanks to trillions of dollars of new federal funding. The American Rescue Plan Act and the Infrastructure Investment and Jobs Act represent the largest infrastructure appropriations in decades. Yet while the scale of this new government funding is historic, it must be used wisely to provide returns on investment for decades to come.

The authors advocate for investment in digital infrastructure that incorporates hardware (like Internet of Things (IoT) devices), data software, platforms for analysis and collaboration, advanced data capabilities (to both manage and protect data), and a smart governance structure to oversee these tools through policy and regulation. Digital infrastructure assists in managing public assets, scheduling maintenance and monitoring safety, improving sustainability and accessibility, and prioritizing equity in investment, health, and quality of life.

Digital infrastructure supports broadly beneficial, important goals. For example, improving roads in Black communities not only combats historic disinvestment but also increases safety by establishing safe bike lanes and pedestrian paths. This in turn causes positive impact on public health through increased physical activity, decreased automobile emissions, and fewer traffic fatalities.[1] While governments can improve road conditions without digital infrastructure, the data collected from intelligent tools like air quality sensors and traffic cameras empowers local officials to measure progress more easily and detect – and implement – necessary changes. Digital tools can facilitate faster and more expansive public engagement, inviting the community to codesign new infrastructure and vote on improvements.

Digital infrastructure necessitates nuanced digital and data governance. As the physical environment changes, so too must city policy. We recommend that local leaders take these approaches to maximize the impact and potential of digital infrastructure: increase administrative capacity to manage both connected infrastructure and resulting data; center privacy and data security; plan for transparency and share open data, particularly with groups that have previously been targets of oversurveillance; increase community engagement at all stages of infrastructure planning; prioritize equity in timelines, funding decisions, and quality of life improvements; and engage legal support around vendor technology, data protection, and data sharing.

If cities can facilitate these changes in governance and create or retrofit digital, connected infrastructure, they will be well-positioned to use the new federal funding to address the harms of the past and build safer, healthier, and more equitable futures.

Introduction

The American Society of Civil Engineers has chronicled the deterioration of U.S. infrastructure, from ports to bridges to wastewater systems.[2] Substantial weaknesses extend from aging and insufficient roads and bridges to unsafe ports and transit systems; from weak electrical grids and levees to toxic water systems; from asbestos-riddled public schools to contaminated waste management and treatment. All too often these failings are concentrated in communities of color.[3] As we wrote in a previous paper, *Toward a Smarter Future: Building Back Better with Intelligent Civil Infrastructure -- Smart Sensors and Self-Monitoring Civil Works,* "since the 1960s, when most of the country's major civil infrastructure systems were designed, the U.S. population has more than doubled. Now, the nation's infrastructure is in urgent need of upgrade and expansion as it extends beyond its useful lifespan."[4]

This substantial problem presents a generational opportunity in part because of record amounts of federal funding to address it. Since 2021 Washington has authorized more than three trillion dollars in relief and infrastructure funds through the American Rescue Plan Act ($1.9 trillion) and the Infrastructure Investment and Jobs Act, also known as the Bipartisan Infrastructure Bill ($1.2 trillion). This new, massive infrastructure investment is the first to occur since the widespread application of digital breakthroughs such as Internet of Things (IoT) connectivity.

Policy opportunities, more than the number of projects, frame the importance of the moment. The current administration, in both executive orders and legislation, calls out sustainability and equity as overarching goals, repeatedly encouraging community participation. Even the very word "infrastructure" fails to capture the importance of this new era. According to Harvard professor and former Massachusetts transportation official Alan Altshuler, "infrastructure" replaced the phrase "public works" in the 1980s and almost completely eclipsed it by 2006.[5] Journalist Alex Marshall suggested that the word infrastructure helped shift the public conversation from focusing on a single public work to analyzing interconnected projects.[6] At the time he wrote, in 2015, Marshall appeared to be considering connectivity in terms of linked projects such as bridges, sewers, and roads. Now, with breakthrough technologies and record funding, governments can attain policy goals – but only if we expand the meaning of and approach to infrastructure to include a physical and intelligent digital foundation to undergird important public systems.

1. About Digital Infrastructure

While infrastructure needs a new definition, it is even more important to develop a new language that incorporates the power of digital approaches. Digital infrastructure should be considered as including one or more of the following components:

(1) **Hardware** including IoT devices, 5G cells facilitating edge computing, and microprocessors

(2) **Software** to integrate sources of data and provide a mechanism for customizing distribution of data to those who need it

(3) **Platforms**, including hardware and software, empowering users to layer and visualize data that facilitates self-monitoring and improved decision making

(4) **Data capabilities** including a strategy for data acquisition, analysis, and maintenance coupled with iterative feedback loops designed for constant adaptability

(5) **Governance structure** framework that facilitates the use of intelligent infrastructure and establishes policies based on data while protecting privacy, security, and communities

While sensors and smart technology are not new, their broadscale integration into civil infrastructure is still in its infancy, despite the vast promise of these innovations to revolutionize the design, delivery, maintenance, and operation of public works. IoT-connected sensor networks change how things and people communicate with each other and provide much more accurate and faster information. The ubiquitous cell phone now facilitates access to resources in ways that could not have been imagined during the last major highway and road funding period. Open data practices enable companies making logistic choices to interact not only with Waze or other third-party systems but secure near-instant information from the city itself. IoT sensors can alert officials and the public alike of dangers. In short everything has changed, except for our definition of infrastructure.

Infrastructure needs to be reconceived in a way that catalyzes broader, bolder systems responses. It no longer means just the physical "structure below," and it is even more than just building and maintaining better. America must focus on "building back smarter." Expanding infrastructure to include digital components will allow system approaches to critical issues like equity, sustainability, and accessibility, crucial for hundreds of millions of urban residents across the country. The data flowing from infrastructure in this broader sense of the word allows officials to deploy nimble system interventions that will produce more public value.

I. What Can Digital Infrastructure Do

Digital tools that help us build intelligent infrastructure require and allow public officials to act across agencies and projects. For instance, although new funding will be

allocated to buses, rails, roads, and bike lanes, officials also need to use those funds to build the digital infrastructure that allows them to manage not a mode, but an entire system for moving people and goods. In so doing, cities gain insights into interconnected issues like transportation emissions, air quality, and equity. Building roads that move cars without also understanding and managing the effect of the carbon and particulates from that traffic on public health and safety will miss the larger imperative.

As scholar Jeremy Millard suggests, these technologies mean that government can do more with more, not more with less.[7] More data can produce more public value if government assists in creating the foundation (or governance structure), including rules for interoperability and privacy. Digital infrastructure includes geographic information systems (GIS) as well, since spatially layered information demonstrates the results of programs on race and place. Advances in cloud computing and GPS positioning support spatial analytics and IoT visualizations that help communities envision and manage interlocking parts of a system. In this sense GIS systems themselves are not just a way of showing infrastructure; they are a critical component of digital infrastructure.

We need digital infrastructure not only to determine how infrastructure is designed and built but also how it is operated and maintained. As engineers can now effectively aggregate real-world data—computer-aided design (CAD), GIS, building information management (BIM), light detection and ranging (LiDAR), photogrammetry, and more—and use that data to create models of their projects quickly, so too must we use intelligent infrastructure to make better informed and timelier decisions about maintaining, repairing, or even changing the use of our infrastructure. Failure to do so will result in new infrastructure inventory being perpetually at risk: the exact quagmire we are currently trying to escape.[8]

Digital infrastructure facilitates "digital twinning," a virtual representation of system effects using real-time data. A digital twin helps officials model the effects of a change across the relevant components of a system. These structures, which include hardware, software, and administrative support, not only power better systems outcomes; they also facilitate improved approaches to community engagement. The digital hardware, software, and administrative infrastructure allows multiple parties to concurrently speak, listen, and learn about matters important to a community's quality of life. Local government, in this new model, engages residents, public employees, and nonprofit and private sector partners through a connected network that produces knowledge and more understanding of a common civic agenda.

II. Why Now

Aging infrastructure and substantial federal funding by themselves have produced an unusual point in time for addressing infrastructure. A confluence of other factors dramatically increases the importance of this moment.

Climate concerns dominate public conversations. For cities, this means more severe weather catastrophes produce stress on flood control protection such as levees and dams, and water systems for drinking, wastewater, and storm management, including those that should mitigate combined sewer overflows. Air quality from carbon emission, wildfires, and particulates endangers residents of many urban communities. Extreme heat requires local action such as cooling stations and wellness checks to assist vulnerable populations.

A new, pronounced interest in remedying long-standing inequities provides another reason to include digital infrastructure. Previous investments often aggravated inequities—whether by placing elevated highways in neighborhoods of color or designing one-way streets that increased vehicle volumes and carbon emissions, or by simply failing to make the necessary investments in clean water, land, parks, and bike lanes in communities of color.

Digital infrastructure expands the methods for community involvement, providing yet another reason why this moment is so propitious for rethinking infrastructure. Extensive personal use of digital maps, as well as virtual/hybrid community meetings, augmented reality tools for design experimentation with the public, and social platforms utilized for neighborhood conversations enhance community involvement in the design, use, and iterations of infrastructure.

Local government can use its role as digital platform provider to bring together and manage urban systems. A system response will look at and attempt to affect the actions not just of agencies but also of public and private actors. In doing so, local leaders make information more easily available and understandable, assisting individuals and organizations in making better choices about where and how to live, play, advocate, work, and travel.

2. Five Ways Using Digital Infrastructure Furthers Equity, Sustainability, and Community Engagement

Equity and sustainability carry with them the characteristics of problems that are sometimes called “wicked” or “grand challenges” because they feature “multiple, overlapping, interconnected subsets of problems that cut across policy domains,” and because they are “endemic, multi-scalar, and evolving.”[9] The solutions to these problems extend across sectors and require a way to continuously incorporate new knowledge into the design and delivery of collaborative actions.

Climate and sustainability raise these multiple interconnected subsets of problems as city officials wrestle with overlapping ecosystems where success depends on a broad range of government actions creating changes in an even broader set of individual actors. Both equity and sustainability require a system response which depends on digital infrastructure, and the data it produces, to bring together communities and galvanize action.

The White House, in its Executive Order on Advancing Racial Equity and Support for Underserved Communities, defines equity in the following way:

> (a) The term "equity" means the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment, such as Black, Latino, and Indigenous and Native American persons, Asian Americans and Pacific Islanders and other persons of color; members of religious minorities; lesbian, gay, bisexual, transgender, and queer (LGBTQ+) persons; persons with disabilities; persons who live in rural areas; and persons otherwise adversely affected by persistent poverty or inequality.
>
> (b) The term "underserved communities" refers to populations sharing a particular characteristic, as well as geographic communities, that have been systematically denied a full opportunity to participate in aspects of economic, social, and civic life, as exemplified by the list in the preceding definition of "equity."[10]

Officials will more likely make progress on the issues of equity and sustainability if, when drawing up capital plans, they include each of the following elements concerning digital infrastructure.

I. Use Maps to Visualize Inequity In, or Caused by, Previous Investments

For capital planning purposes city officials need to map previous investments community by community including spending on parks, sewers, clean water, and streets. However, the mapping needs to be layered so that it shows both lack of investment and the consequences of earlier decisions. For example, spatial analysis will show the hyper-local public health consequences of these earlier investment decisions, like concentrated air pollution in Black neighborhoods.[11] GIS visualizations can reveal the neighborhood-level effects resulting from previous projects.

II. Provide Digital Platforms that Improve Life in Underserved Communities

A second way to produce more equitable results is by constructing digital platforms that further innovative solutions in underserved areas. The Justice40 Executive Order establishes that 40 percent of the overall benefits of investments should flow to communities that are marginalized, underserved, and overburdened by pollution.[12] This Executive Order applies to a wide number of environmental programs, but a more comprehensive approach to

equity would consider how other federal infrastructure grants affect Justice40 communities. For example, traffic safety problems disproportionately affect Justice40 neighborhoods. According to a recent paper by Matthew Raifman and Ernani Choma, fatality rates per 100 million miles traveled are systematically higher for Black and Hispanic Americans for all modes and notably higher for vulnerable modes – while cycling, Black Americans died at more than four times the rate for white Americans, and more than twice the rate while walking.[13] Thus cities working on issues of safety and applying for federal funding should seek to use digital infrastructure to bring together data on, and solutions to, problems that disproportionately affect marginalized communities in the related areas of transportation and energy as well.

Public health is a part of sustainability, from urban green spaces[14] to pollution and asthma[15] to traffic deaths.[16] Air quality is very clearly linked to health outcomes. Poor air quality more often occurs in neighborhoods of color, which are more likely to be located near factories, highways, and major roads. Miami, Florida is frequently considered the epicenter for climate crises in the United States; the city's increasingly strong hurricanes, floods, and heat pose a considerable threat to residents' health and safety.[17] Miami's senior data scientist, Jennifer Hernandez, works across city (and county) agencies to assemble and map data on environmental threats and then co-create solutions. This data comes from residents, who can act as citizen-scientists through the ISeaChange app, call 311 to report flooding, and get in touch with local representatives about environmental hazards, and from city sensors that track energy usage, coastal water levels, and heat islands.[18] By combining intelligent infrastructure with community voices, Miami is a leader in smart, data-driven approaches to the climate crisis.

III. Build a Digital Infrastructure That Monitors Conditions in Real-Time

Local leaders may engage in projects to reduce dangerous emissions and improve air quality, but without the ability to check progress there is a strong possibility of backsliding. For example, air quality has improved significantly throughout the country since the Clean Air Act in 1970 (with additional amendments in the 1990s).[19] However, improvements have been inequitable; hyper-local research shows that communities of color suffer from far greater levels of air pollution and experience the most co-morbidities.[20] Infrastructure equipped with small, inexpensive air quality sensors can be placed in these areas to regularly check pollution levels and ensure that progress on reducing particulate matter is experienced equitably. Similarly, capturing real-time information on water quality and temperature enables fairer and more rapid interventions.

IV. Use Sensors to Redefine Resiliency

Building infrastructure to be resistant to climate change-related disasters[21] involves utilizing new materials to repair and retro-fit current infrastructure to withstand extreme

heat, flooding, and storms.[22] Luna Lu, the American Concrete Pavement Association professor and director of the Center for Intelligent Infrastructure at Purdue University, defines intelligent infrastructure as infrastructure that is "safe, sustainable, resilient, and adaptive." Speaking at our June 2022 event, Lu emphasized that traditional road construction methods are not optimized for cost, materials, or time. Her research and experimentation with nanotechnologies and sensors led to significant breakthroughs for building new roads and patching older roadways.

In cold-weather locales, traditional concrete faces a freeze-thaw issue. Water enters small cracks, expands when frozen, making the crack larger, then that ice melts and the cycle repeats. Lu and her team developed a novel nano-silica admixture which, when combined with concrete, becomes self-healing.[23] Much like a scab on human skin, concrete with the nano-silica particles will heal cracks by itself in approximately 28 days – and after re-healing, the area is stronger than the original concrete. The self-healing road materials produce cascading reductions in cement usage, water usage, traffic, and CO2 emissions. The techno-materials can be applied to cracks in regular concrete or used for full paving, in alignment with a two-pronged sustainability approach. We use this as just one example of the need for chief data officers, chief information officers, and chief technical officers to play a role in ensuring that digital breakthroughs find their way into traditional procurements.

V. Expand Community Engagement

One vital component of equity is community engagement; after all, without talking to the community and learning from voices that have historically been marginalized, how can cities guarantee that new policies and projects are equitable? At our June 2022 Working Group on Digital Infrastructure, Equity, and Sustainability meeting, Clarence Wardell, the chief data and equitable delivery officer for the White House's American Rescue Plan, outlined three key principles for cities to follow as local leaders embark on new, equitable infrastructure projects:

(1) Set the right project goals and outcomes at the start in order to lead with equity.

(2) Allocate and leverage resources with community organizations, universities, and the private sector.

(3) Measure the impact of programs to replicate successful ones and change or eliminate unsuccessful interventions.

These principles bring into focus the need to use digital tools to involve the community in new and broader ways. As we set out in a recent paper, *The Responsive City Cycle*, digital

outreach provides a means for officials to hear from diverse voices, especially those who do not regularly show up at community meetings or petition government with their grievances. Sentiment mining from anonymized social media discussions allows planners to consider community-level discussions of traffic, safety, and parks. Polling augments these results if it is structured to give proper weight to underrepresented communities.

Digital engagement, including requests for residents to text back answers to questions, as well as augmented reality virtual charrettes, produce more community engagement. Incorporating a digital infrastructure that facilitates local government's opinion-gathering from residents of underserved communities will increase their voice and enhance the likelihood that new investments will address the priorities of the community, in design of investments and in ongoing questions about use and management.

3. Intelligent Infrastructure Moves Us Towards Important Objectives

In terms of integrating the components above to address wicked problems, the following examples provide guidance on advancing equity, sustainability, and engagement with digital infrastructure.

I. Intersection Safety

Safety in most cities continues to worsen, and the federal government has allocated substantial funding to address the issue. According to the latest edition of the S*ignalized Intersections Informational Guide*, published by the US Department of Transportation in 2013, nearly 40 percent of crashes took place at intersections (both signalized and non-signalized), resulting in 46 percent of total fatalities. In a more recent analysis by the National Highway Traffic Safety Administration, the total number of pedestrian fatalities increased by 46 percent during 2010-2019.[24]

Traffic safety is also an urgent challenge to equity. Recent research from the Boston University School of Public Health and Harvard T.H. Chan School of Public Health indicates that Black and Hispanic Americans face higher traffic fatality rates per mile traveled compared to white Americans across different transport modes.[25] While additional studies will further examine these disparities,[26] improving traffic safety across different communities is undoubtedly a critical response to structural inequity in our society.

Intersection safety can be increased through a combination of design and operational issues. Intersection management needs to be customized to accommodate the volume of pedestrians, bikes, high-speed approaches, and truck traffic. Sources of information can include IoT sensors, cameras, connected vehicles, intersection signals, neighborhood complaints, accidents, detection of red light running and hard braking, and more. Analytics can predict risks and manage intersections in real time.

We use intersection safety to underscore the power of digital infrastructure -- incorporating sensors into construction; providing a platform to ingest all the relevant information, and then developing analytic capacity to operationalize it. the. Another component of digital infrastructure, GIS, can overlay risk and dangerousness with various demographic and neighborhood characteristics to visualize how risk is disproportionate in underserved neighborhoods. Analytics can uncover a range of causal factors including the rate of vehicles entering intersections late, the volume and timing of pedestrians and bikes, and accident information. Vehicle-specific sensors can provide priority and warnings to emergency vehicles and transit and school buses.

Advances in machine learning algorithms and the increased capacities of sensors are creating additional protections at intersections. At our June event, Nader Ayoub, formerly with Texas DoT and now an engineer with Iteris, Inc., explained how an advanced system would combine traditional traffic signal controllers and connected vehicle data with video detection technology and other sensors to optimize signal operation for safety purposes and congestion. With video detecting pedestrians, cyclists, and cars, and radar sensors measuring car speed, an integrated intersection system can make alterations in real time. For example, the signal control system might gauge the size of the decision zone (the area that occurs when a traffic signal turns yellow before turning red) for each passing vehicle, even making adjustments to protect the intersection from potential red-light runners.

An important advantage of the integrated sensors system is the capacity to accumulate traffic data. For instance, Masoud Hamedi, director of Data Science at Iteris, introduced a collaboration between Iteris and the Florida Department of Transportation (FDOT) in Tampa. Iteris manages approximately 500 road intersections in District Seven, which constitute almost 20 percent of signalized intersections in the state.[27] The integrated data enables a crash protection model and a risk score calculation that ranks hard braking and acceleration. According to Hamedi, Tampa benefitted from information from connected vehicle data -- and now Tampa experts aided by the Iteris team can develop a crash protection model and a risk score calculation.

Other solutions can be added onto a digital platform, such as the HAAS Alert system, a cloud-based warning system for road safety. As soon as a first responder begins to flash its light, HAAS Alert delivers real-time notifications to nearby drivers via driving apps, in-vehicle navigation systems, or mobile devices. The system extends the alert window for approaching drivers from three seconds to up to 20 seconds, allowing drivers to slow their speed and avoid collisions.[28]

II. Curb and Sidewalk Management

Another illustrative application of a system approach that uses digital tools to advance sustainability and equity involves curb and sidewalk management, as cities slowly shift from

viewing taxi, transportation network companies (TNCs), bikes, and transit as independent areas of regulation to seeing them as components of transit. In this sense the uses of the sidewalk constitute the system. As the famous urbanist Jane Jacobs said, "Streets and their sidewalks –the main public places of a city–are its most vital organs."[29] A system approach ingests and analyzes data to produce a regulatory framework that encourages optimal uses. Regulators looking at quality of life planning and the sidewalk as an important public space need to understand pedestrian traffic, curbside parking, outdoor dining, commercial deliveries, and scooter and bike drop off locations as connected pieces. This sidewalk system incorporates the needs of adjoining retailers and residents. Curb and sidewalk planning and management requires a platform that city leaders can use to set rules and that consumers can consult to choose how they interact and travel.

Curb and sidewalk systems help illustrate the application of digital infrastructure. Clearly a software platform to ingest applicable data is critical to helping consumers and regulators referee competing uses. Yet that platform will only succeed if accompanied by a strategy for data acquisition and analysis, and that requires a governance structure set up by the city that sets rules on technical protocols. The availability of micro-mobility, bike sharing, and anonymized cell phone usage data has produced abundant data. However, the work related to regulating the usage of the data is falling behind. At one level we need data requirements that produce interoperability, building off the previously established General Transit Feed Specification (GTFS) which addresses data produced from various transport modes and across jurisdictions.

As Andrew Salzberg, formerly of Uber and currently at the Massachusetts Institute of Technology, pointed out during our 2022 event, addressing these issues requires that public and private actors work together. Salzberg advocates for exploring further the example of General Bikeshare Feed Specification (GBFS), which focuses on data produced from micro-mobility services.[30] GBFS is a critical step to making the data publicly accessible and comprehensible, especially at scale, with a strong governing network of over 601 bikeshare and scooter systems worldwide.[31]

Andrew Glass Hastings, the executive director of the Open Mobility Foundation (OMF), emphasized the need for intelligent infrastructure governance to produce a consistent approach to ingesting data connected to street and curb use and regulations. To accomplish that goal OMF proposes a Curb Data Specification (CDS) that facilitates the communication between cities, curb users, and technology providers. CDS consists of a variety of APIs allowing regulating, measuring and documenting real-time events at and near curbs– including recurring and temporary events, commercial deliveries, schedules, parking, and so forth. In that sense, CDS becomes an important part of the governance which helps regulators guide the most valuable use of sidewalk and curb usage. CDS, like GBFS, gives consumers more complete information when they are making decisions. Even with these tools in place cities still will need to adopt clear policies on security and privacy that extend to those they regulate and their contractors.

4. Digital Culture and Policy Infrastructure

The original definition of infrastructure meant the underground structures that supported commerce, transportation, and utilities. Modern infrastructure needs to include the necessary policy components that support digital systems solutions (and vice versa). A connected and open environment requires governance to protect public values regardless of whether a government actor or an authorized private contractor furnishes the application, function, or supplies. Government is responsible for setting standards, including for privacy and security protections. Information generated from thousands of different sources that, when curated and acted upon, produce public value "is no longer defined or contained as a discrete entity . . . but becomes more flexible and mobile as it is processed in and across a variety of systems and applications."[32] Trust, integrity, and accountability depend on how easily information can be digested and utilized and how comfortable individuals are that their privacy will be protected.

Issues of data governance will apply when a city regulates a service, grants a license to use its right of ways for a commercial concession (for example, electric vehicle charging or right of way information kiosks such as the LINKNYC structures in New York), when it conducts activities itself, or when it contracts with providers.

When a city regulates an external partner, it can request certain data be shared and insist on standards for interoperability. For example, in 2012 New York City leaders and yellow cab owners disputed whether the cabs were providing fair access to the city's outer boroughs. Without data, this issue might have hit a stalemate. Yet the Taxi and Limousine Commission required that cabs provide anonymized location data every time their meters started on a ride providing invaluable information to the debate. Visualizations showed that only 2.5 percent of rides occurred outside of Manhattan, confirming suspicions that drivers were not providing equal access to the outer boroughs. This well-conceived data infrastructure and the ability to share data among stakeholders supports the notion that better services come from better data systems. Digital infrastructure should allow ingestion of data from private parties whose services affect applicable systems — which all depends on the right regulations and the right supporting software platform.

It is not easy to know where to draw lines in order to improve service, protect privacy, and not overstep proprietary IP and other competitive secrets. These very issues have proven contentious in many cities, particularly in relation to TNC regulations. Major cities like Los Angeles and Chicago have run into problems when trying to regulate ridesharing; finding the right balance can require trial and error. Data utilized for quality-of-life planning and management can be highly effective – yet at the same time, uncontrolled access can be dangerous.

Rethinking the meaning of infrastructure and setting up the necessary policies requires and encourages a cultural shift in government. Local governments need to use digital means

to break down information and agency siloes. Collaboration among agencies and departments based on data garnered from digital infrastructure will improve government outputs and allow greater efficiency in tackling complex problems. However, this cultural shift demands changes to the collection and protection of data. The state of Colorado in its *Data Security Best Practices*[33] and the federal government in its *Federal Data Strategies*[34] provide examples of comprehensive data protection approaches. Additionally, the consulting firm McKinsey & Company reported on various data management best practices using international examples to illustrate several approaches to interoperability and privacy.[35] Systems responses and ease of data exchange that produce a higher quality of urban life through government-supported infrastructure platforms require protocols that support each of these areas.

Good results require clear guidelines flexibly applied—privacy and security controlled by policies and refined by design—rather than overly detailed policies, as they will vary by use and participant. Most interventions that advance equity and sustainability present complex questions associated with data. Progress depends on understanding, and often changing, the behaviors of individuals.

Creating a data infrastructure that facilitates exchanges by and with multiple parties will require innovations driven by private sector investments. These investments in turn require confidence that a local government will continue to provide a platform that furthers interoperable use and sets reasonable rules for exchange in a way that protects proprietary IP. Setting this foundation correctly is a complex process that needs careful attention.

Our recommendations for a governance approach follow a few basic principles. The digital governance infrastructure should remain flexible and dynamic while pursuing these objectives: transparency, privacy limitations proportionate to the sensitivity of the information, equity and sustainability, and balancing of benefit and risk.

1. **Increase administrative capacity:** Cities should utilize flexible ARPA funds to build the necessary human resources to support digital solutions, including individuals who can provide analytic, procurement and legal capacity. Digital platforms deliver system solutions only if accompanied by a central point of expertise that can assist cross-agency implementation decisions. This node should work with procurement teams, departments of transportation and public works, and community engagement offices to expedite implementation for creative, nontraditional responses.

2. **Center privacy and security:** Cities should adopt comprehensive privacy policies. Those rules should consider internal and contractor management of personal information acquired as part of a transaction or use, and incorporate methods for auditing compliance. In addition, cities need to expand security capacity to protect their IoT vulnerabilities.

3. **Plan for transparency and open data:** As millions of dollars flood into cities through federal infrastructure programs, agencies must work together to document the money coming in, where that funding is going, which groups are being contracted, and what sites or structures are being developed. A few examples already exist of cities with federal fund tracking; in Syracuse, New York, Mayor Ben Walsh announced a new ARPA Dashboard tracking tool in early 2022, which visualizes both project and spending progress.[36] Additionally, cities need transparency not just in the spending, but also in data collection and analysis. Cities have been moving toward open, shared data for many years, and as intelligent, connected, and data-gathering infrastructure is developed, cities must extend open data policies to include it.

4. **Increase community engagement:** In Detroit, Michigan, city leaders launched a vigorous public campaign around ARPA spending, encouraging residents to #TakePart in numerous public meetings and virtual information sessions where they could make their voices heard and raise priorities for ARPA funding.[37] Considering the historic disregard for low-income, immigrant, and communities of color in older infrastructure development, engaging community members through multiple avenues is crucially important at the start of any new federally-funded work.

5. **Prioritize equity:** The White House has explicitly laid out equity goals associated with the new infrastructure funding. Several cities have utilized mapping to show where historic investments were made, how close Black and Hispanic communities are to things like bike lanes and parks, and the accessibility of jobs by transit. In San Diego, Chief of Race and Equity Kim Desmond and Chief Innovation Officer Kirby Brady work closely together to collect, analyze, and map data; turn that information into actionable equity policies; then measure progress on these policies through data to ensure accountability. Their partnership offers a nationally-significant example of integrating and operationalizing equity, and one that can be coupled with infrastructure-related agencies. Additionally, other long-standing equity impacts stem from investing in improved infrastructure. In a recent interview on our podcast, the Data-Smart City Pod, Hilary Rau, the vice president of policy and community engagement at the Center for Policing Equity, stated that sometimes “an infrastructure change is a better

solution to saving life than flooding an area with police officers."[38] Rau pointed out that the disinvestment in historically Black neighborhoods led to worse street and infrastructure conditions, which in turn resulted in greater police presence (due to things like traffic violations or crashes).

6. **Engage legal support.** Multiple legal issues append to the introduction of digital processes, including some related to contracting and privacy. Other issues involve data-sharing among departments. When bringing agencies together, a central point of legal authority, with experience including in issues of tech IP as well as federal laws concerning data, will result in much quicker resolution of difficult issues.

Conclusion

Local officials find themselves at an interesting intersection of challenge and opportunity. The COVID-19 pandemic rapidly shifted land use and downtown areas while revealing the warped truth about income and health inequality. Aging infrastructure and climate-driven catastrophes produce uncertainty around the globe. At the same time, the federal government is providing extraordinary amounts of funding to local and state governments, and technological breakthroughs provide previously unimagined chances for positive change.

Achieving positive change depends on spending new money in new ways. Previous capital decisions, public works, and investments compounded inequities and limited the connectivity of space and insights. Capital planning should start at the system level—not at the project level. And the infrastructure that supports a system approach must be intelligent; it must include the software, hardware, governance, and platforms required for transformative progress. These tools exist. Only imagination will hold us back from improved quality of life.

Residents and local leaders alike are looking for broad, positive change. Digital infrastructure and the corresponding governance policies can achieve this, and not just for a brief moment. Building back better requires envisioning how current tools and decisions will continue to create healthy societies far into the future, and realizing the tremendous potential of digital, connected infrastructure.

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