How Cities Make Software Together

An exploration of how orchestrated development is improving municipal digital infrastructure

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Infrastructure is having a moment in America. With the passage of the Inflation Reduction Act - AKA the Bilateral Infrastructure Law - the country as a whole is focussed on the state of our crumbling public infrastructure. And infrastructure is often our lifeline that connects our jobs to our homes, our schools, our health care facilities and other critical needs. But less focus has been given to the role of municipal digital infrastructure, which is just as critical as a connector of government to its citizens.

We take for granted all that is necessary to connect government services to its citizens and the invisible municipal infrastructure that powers the delivery of government services to the public. The Jacobs UT Hub at Cornell Tech was launched in 2020 to help identify the roles that government, communities, academia and industry fills. In this research, we've identified the complementary roles that governments, intermediaries and funders play in helping to shape, scale and sustain the creation and development of digital municipal infrastructure. We've dubbed it "Orchestrated Development" and it includes key roles for three types of actors in the creation of municipal digital infrastructure.

- **Governments - Spark** ideas by establishing guiding principles and setting goals.

- **Intermediaries - Scale** innovations into practice for meaningful objectives that substantially serve those in need.

- **Funders - Sustain** efforts by creating the institutional pillars of support—financial, policy, and technical infrastructure—that ensures municipal digital infrastructure evolves, performs, and persists over time.

This is an incredibly important collection of players who contribute to the process of creating the conditions to produce resilient municipal infrastructure and Open Source Software. Many cities and counties are not large enough to do it on their own, and the case studies cited in this report gives concrete evidence that cities can play an important role in the creation of new software through partnerships with intermediaries and nonprofit organizations.

This project is a prime example of the type of work that the Hub was built for, to help shine a light on the gaps that exist between the multiple players in the urban tech ecosystem. With a threefold mission of 1) sharing knowledge in urban technology, 2) advancing applied urban tech research and 3) expanding the ecosystem of players engaged in urban tech by bringing together academics, government officials and industry leaders.

Speaking of the importance of nonprofit partners, we'd like to thank the sponsors of this report for their support for this effort. This research was funded by a grant from the Digital Infrastructure Fund, a program of Ford Foundation, Sloan Foundation, Mozilla, Omidyar Network, and Open Society Foundations and special thanks to all of the participants from the case study cities who generously shared their time and insights.

We hope that you enjoy reading this report, and also hope this is the beginning of a conversation and a renewed effort to bring together a vibrant, innovative and resilient community of sparkers, scalers and sustainers to help improve government service delivery to the public.

Sincerely,

Michael M. Samuelian, FAIA, AICP
Founding Director, Urban Tech Hub
Jacobs-Technion Cornell Institute, Cornell Tech

Contents

What is municipal digital infrastructure?

Municipal governments are riding a volatile wave of economic, ecological, and social change. But one thing is constant—the accelerating spread of digital technologies. These tools are changing how cities work, creating new challenges. But they also create new opportunities for problem-solving.

Software is the code that organizes computation to do work. And software is at the center of today's digital urban restructuring. Municipal governments are learning how to use software to measure, analyze, and optimize service delivery. They are instrumenting and automating the physical infrastructure of buildings, utility networks, and vehicles. But cities are also exploring how software can bring hidden processes and concerns to the surface and expand civic participation. For all these reasons, cities' software needs are expanding exponentially.

But even as cities rely more on software to function, they struggle to obtain and maintain software. Traditionally, code is procured from the private sector, or—less often—produced in-house. But these mechanisms are slow, costly, and often fail to deliver innovation. Software vendors often fill in these gaps, locking in costly dependencies on inflexible products.

Open source software presents a third possibility for cities to fulfill their software needs. It also offers the potential for greater autonomy and lower cost.

Since the rise of open source in the late 1990s, many cities have developed open source software. But along the way, cities have learned an important lesson—open source is hard. They struggle finding competent and cost-effective vendors to build or support products, training staff to use new tools, and designing procurement policies that account for the benefits of open source software.[1] Open source requires enormous effort to create, and even more to deploy and maintain. These processes are just as important as the product.

Nowhere is this priority more clear than when cities team up to pursue open source solutions together. This report examines six case studies of inter-city cooperation on open source software over the last decade, many of which continue today. We call this growing base of code and process *municipal digital infrastructure*.
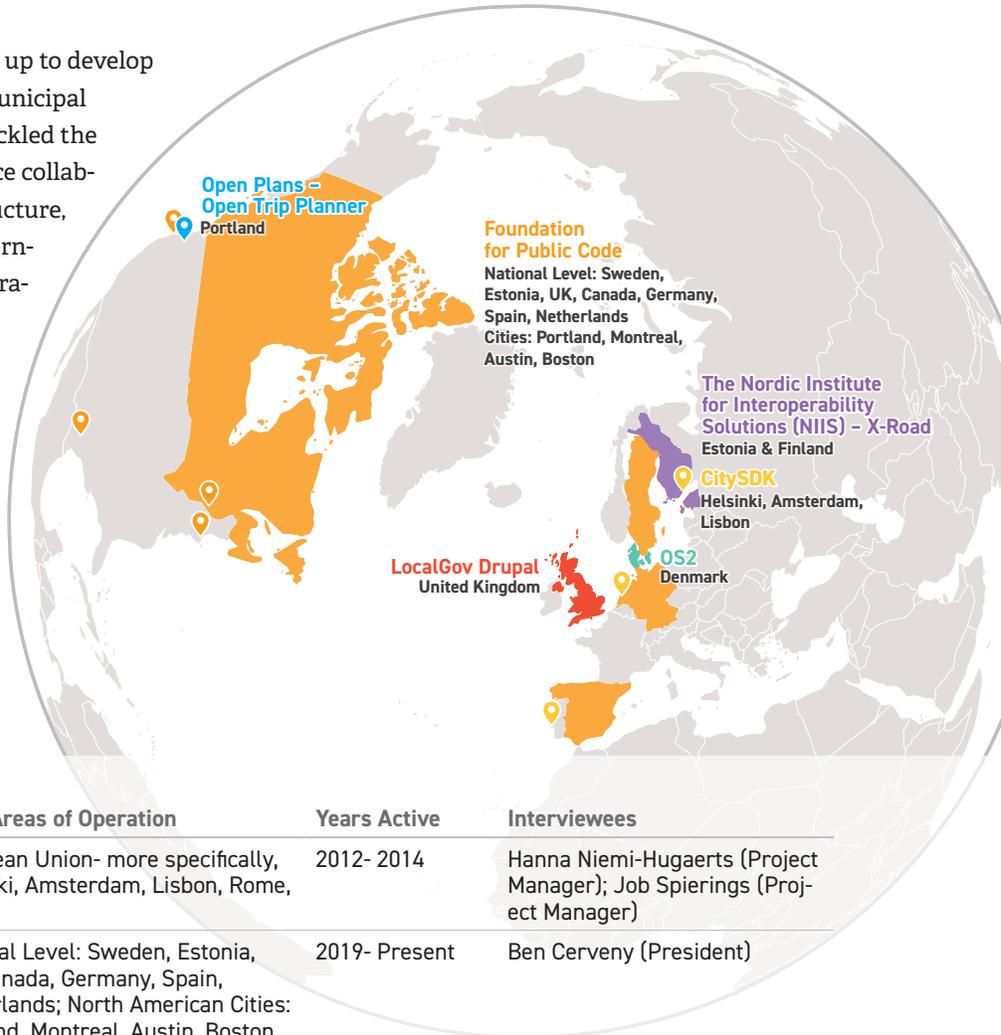
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1   Justin C. Colannino, "Free and Open Source Software in Municipal Procurement: The Challenges and Benefits of Cooperation," Fordham Urban Law Journal 39, no. 4 (2012): 903-929.

Intermediaries are at the center

Municipal digital infrastructure is a specialized class of digital infrastructure, the "software, standards, and protocols that form our digital infrastructure [and] are critical to a free and open internet."[2] Recent research on open source highlights the common goals, methods, and outcomes of collective efforts to produce digital infrastructure. But municipal digital infrastructure has its own set of critical processes.

To reveal why and how cities are teaming up to develop open source together, we examined six municipal digital infrastructure efforts that have tackled the challenge of making inter-city open source collaborations work. Municipal digital infrastructure, by definition, involves multiple local governments working together. But that collaboration needs lots of support, and at the hub of each of the projects we studied, there was an independent, non-governmental organization (NGO) that played a pivotal coordinating role. We call these organizations intermediaries.

> "Municipal digital infrastructure is a specialized class of digital infrastructure, the "software, standards, and protocols that form our digital infrastructure [and] are critical to a free and open internet."

Open Plans – Open Trip Planner
Portland

Foundation for Public Code
National Level: Sweden, Estonia, UK, Canada, Germany, Spain, Netherlands
Cities: Portland, Montreal, Austin, Boston

The Nordic Institute for Interoperability Solutions (NIIS) – X-Road
Estonia & Finland

CitySDK
Helsinki, Amsterdam, Lisbon

LocalGov Drupal
United Kingdom

OS2
Denmark

Intermediary Project	Main Areas of Operation	Years Active	Interviewees
CitySDK	European Union- more specifically, Helsinki, Amsterdam, Lisbon, Rome, Lamia	2012- 2014	Hanna Niemi-Hugaerts (Project Manager); Job Spierings (Project Manager)
Foundation for Public Code	National Level: Sweden, Estonia, UK, Canada, Germany, Spain, Netherlands; North American Cities: Portland, Montreal, Austin, Boston	2019- Present	Ben Cerveny (President)
LocalGov Drupal (renamed "Open Digital Cooperative" as of January 2023)	United Kingdom 28 UK councils	2018- Present	Will Callaghan (Product Lead)
Open Plans (Open Trip Planner)	United States (Portland)	2009- 2011	Kevin Webb (Project Lead)
OS2	Denmark (92 out of 98 municipalities)	2012- Present	Rasmus Frey (Chief Executive and Secretary)
Nordic Institute for Interoperability Solutions (X-Road)	Finland, Estonia, Iceland	2014- Present	Ville Sirviö (Chief Executive Officer); Petteri Kivimäki (Chief Technology Officer)

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2 "Critical Digital Infrastructure Research," Ford Foundation, accessed January 24, 2022, https://www.fordfoundation.org/campaigns/critical-digital-infrastructure-research/.

CitySDK was a collaborative, pan-European effort to create a smart city application ecosystem through large-scale, demand-driven city pilots. Funded by the European Community's Competitiveness and Innovation Framework Programme (CIP), it connected some 29 partners from 9 countries from 2012 to 2014 on application pilots dealing with participation, mobility, and tourism. Three of these pilots involved the creation of standardized APIs under the coordination of Helsinki-based Forum Virium, an NGO—Open311 API (Helsinki), Linked Data API (Amsterdam), and Tourism API (Lisbon). Beyond these initial pilots, CitySDK APIs were also adopted in New York City, Barcelona, Rome, Istanbul, Manchester, and beyond. Due to extensive documentation of CitySDK's practices and codebases, the program's digital legacy still serves as a resource for other global cities to develop their own SDKs (service development kits).

Foundation for Public Code is an NGO that "empowers cities to collaborate on and run their core functions on democratically accountable public code", which it defines as "open source software developed by public organizations, together with the policy and guidance needed for reuse." Founded in 2019, the group works with individual cities and national administrations across Europe and North America to manage project codebases, project documentation, and relationship between municipalities and vendors. A large amount of Foundation for Public Code's effort is spent on outreach and documentation of key processes, which it has distilled into a *Standard for Public Code*, that provides a model for reusable software.

LocalGov Drupal (renamed "Open Digital Cooperative" as of January 2023) is a UK-based initiative started in 2019, that develops and maintains a pre-configured version of the popular open source content-management system Drupal for managing local council websites in the UK and Ireland. The group now works with some 30 local councils across the British Isles and is funded by the UK Ministry of Housing, Communities and Local Government under the 2018 Local Digital Declaration, which prioritized user-centered design, software reuse, and transparency.

Open Plans was founded in 1999 as a non-profit technology and advocacy organization. In the following years, the group developed mapping tools and open source data to foster a more transparent, responsive government and opportunities for civic engagement. One of the organization's early flagship efforts, **Open Trip Planner** (OTP) is a suite of open source projects that provide passenger information and transportation network analysis services. OTP was developed from 2009 in close collaboration with Portland's public mass transit operator (TriMet), and has been deployed by more than 20 governments worldwide. In 2013, the project was reorganized under the auspices of the Software Freedom Conservancy and a self-managed committee.

OS2 is a network of Danish municipalities founded in 2012 that assists in specification, procurement, and governance of open source software. OS2 provides project management services, governance and vendor support for participating municipalities. The organization also works to identify common needs across municipalities, and reduce redundancies. More than 90 percent of Danish municipalities are active members, along with some 68 IT vendors, each paying a fixed annual fee (DKK 25,000: approximately USD 3,500) that supports the organization's small staff.

The Nordic Institute for Interoperability Solutions (NIIS) is a non-profit association with three members—the nations of Estonia, Finland and Iceland—established in 2013 to develop and maintain **X-Road**, an open source stack for secure decentralized data exchange between organizations. More than 20 countries worldwide now use the software. In addition to software development, NIIS supports users by providing online training, hosting annual user community events, and certifying vendors. While not focused on municipal governments, NIIS and X-Road are included in this study because of the tight degree of integration between national and municipal government in Nordic cities, where the bulk of each nation's population and commerce is located—many digital government services delivered by these national governments are de facto municipal services.

Orchestrated development is more than crowdsourcing

Intermediaries are the glue that connects municipalities and external funders (e.g. philanthropies and other levels of government) into cooperative networks that can design, make, use and maintain open source software. We have identified four common processes that intermediaries direct to help municipalities avoid the pitfalls of traditional open source development.

1. **Governing**—Creating a representative structure for setting priorities, making decisions, and working with municipal stakeholders to enact rules that put municipal digital infrastructure in place.

2. **Producing**—Cultivating shared codebases by defining outcomes and standards, and encouraging and incentivizing contributions.

3. **Implementing**—Curating a community of value-aligned vendors who can build, deploy, and maintain open source software and systems over long periods of time.

4. **Learning**—Developing and disseminating documentation and training materials, and cultivating developer and user communities.

These processes link up to create a continuous, sustainable pattern by which multiple municipalities advance open source software together. We call this model *orchestrated development*. (Figure 1). Orchestrated development builds on traditional crowdsourced models of open source software development in three key ways.

First, orchestrated development connects institutions, not individuals.

Open source has traditionally been instigated and led by individuals. Orchestrated development is the work of institutions—in the case of municipal digital infrastructure, city governments. To this, cities bring a long history of cooperation on large and complex innovations.

Second, orchestrated development creates systems, not just code.

Because software engineers drive many open source projects, production is the most important goal. But the work of producing software begins long before code is written. Orchestrated development places equal importance on activities that support and leverage innovative software, and draws upon multiple stakeholders with distinct roles—users who drive adoption, and partners who enable scaling.

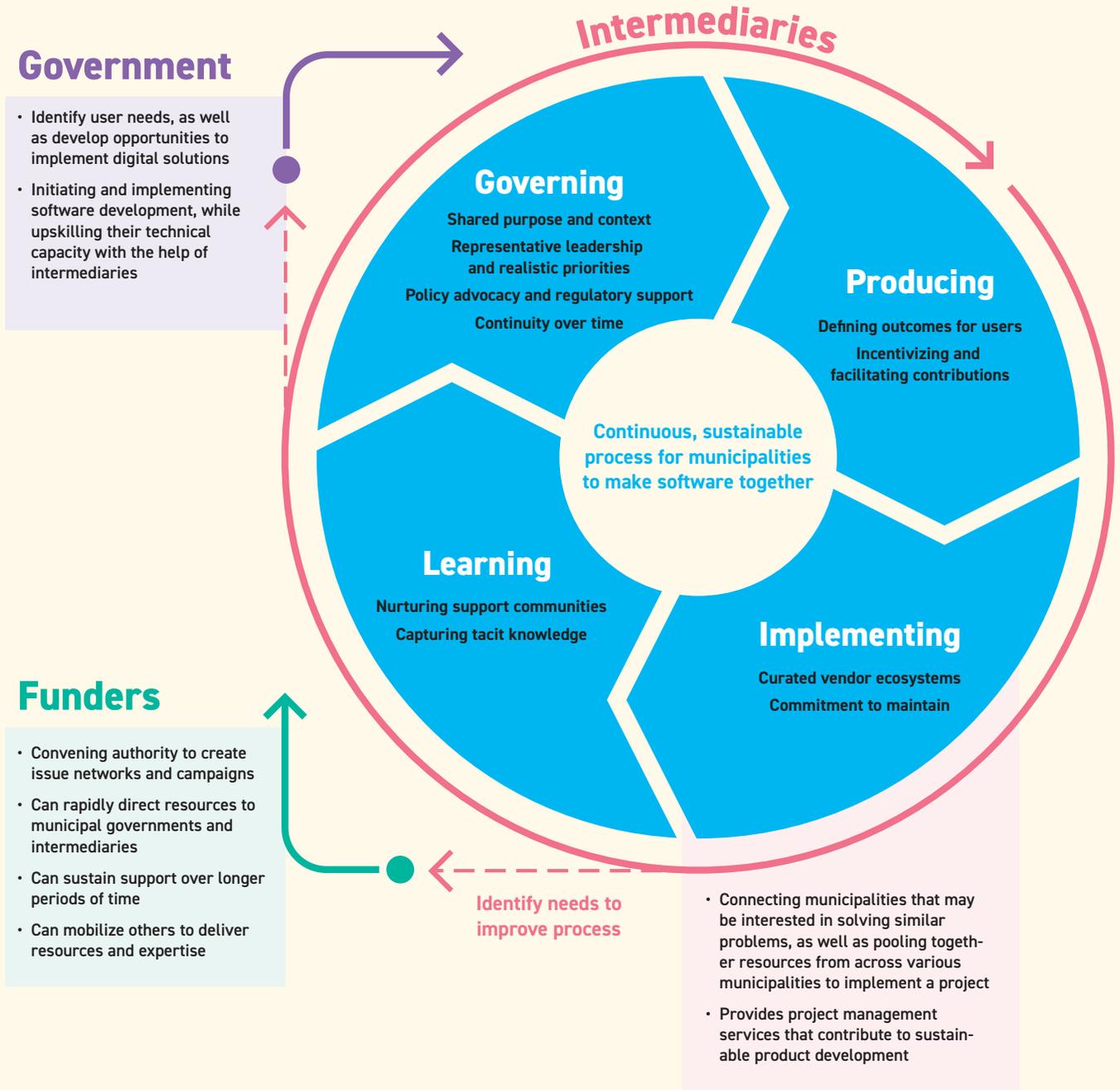## Third, orchestrated development is highly structured.

Because non-production activities are traditionally undervalued in open source development, governance, learning, and implementation are ad hoc, not well-structured, and not sustained. Orchestrated development, by contrast, applies structured approaches to these activities. Orchestrated development values processes as much as the software products themselves.

Although orchestrated development is led by intermediaries, orchestrated development also involves cities and external funders as principals. By focusing on *processes* of municipal digital infrastructure versus software solely as a product, the orchestrated development framework raises important strategic implications for its stakeholders:

- For cities, it highlights the value of active participation in well-designed governance systems, in order to set priorities.

- For intermediaries, it reflects the crucial position and role of these organizations, highlighting both the need and specific challenges for channeling resources to maximize their catalytic potential.

- For funders, it identifies gaps in capacity in the systems that produce and maintain municipal digital infrastructure, as well as potential failure points, providing a tool for assessing where and when to intervene.

In the next section, we describe how the four processes of orchestrated development—governance, production, implementation, and learning—played out in the initiatives we studied.

Figure 1. The Orchestrated Development Process

Government

- Identify user needs, as well as develop opportunities to implement digital solutions
- Initiating and implementing software development, while upskilling their technical capacity with the help of intermediaries

Intermediaries

Governing

Shared purpose and context

Representative leadership and realistic priorities

Policy advocacy and regulatory support

Continuity over time

Producing

Defining outcomes for users

Incentivizing and facilitating contributions

Continuous, sustainable process for municipalities to make software together

Learning

Nurturing support communities

Capturing tacit knowledge

Implementing

Curated vendor ecosystems

Commitment to maintain

Funders

- Convening authority to create issue networks and campaigns
- Can rapidly direct resources to municipal governments and intermediaries
- Can sustain support over longer periods of time
- Can mobilize others to deliver resources and expertise

Identify needs to improve process

- Connecting municipalities that may be interested in solving similar problems, as well as pooling together resources from across various municipalities to implement a project
- Provides project management services that contribute to sustainable product development

How is municipal digital infrastructure made?

In practice the four processes of orchestrated development—governance, production, implementation and learning—are not always strictly separated. For instance, agile software development methods often combine production and implementation into an iterative cycle of design, coding, and testing with end users. However, identifying these processes—which are directed by intermediaries—provides a working framework to organize the key ideas, assets, and practices involved in orchestrated development.

Our design of this framework is based on the experience of leaders from six intermediary organizations—CitySDK, Nordic Institute for Interoperability Solutions, Open Plans, OS2, Foundation for Public Code, and LocalGov Drupal. This information was gathered during a series of interviews in 2021-2022. The individuals involved were responsible for conceiving, delivering, and documenting municipal digital infrastructure projects through these intermediary organizations.

Throughout these interviews, we focused on three big questions:

- What were the most important obstacles to collaborative development, deployment, maintenance, and improvement of municipal digital infrastructure?

- What approaches were useful in overcoming these obstacles, and how did these learnings shape changes in goals and strategy over time?

- What gaps remain, and what opportunities exist for bolstering skills, knowledge, and networks that can improve the capacity and capabilities of municipal digital infrastructure collaborations?

Our initial hypothesis for this research was that most efforts to develop municipal digital infrastructure were unsuccessful, and had not established durable communities around their products. We hoped to identify ways to fix these broken systems.What we discovered as we documented the work of intermediaries was an entirely different picture. What we found were highly effective organizations mobilizing vast networks of resources with, and on behalf of, city governments.

This section summarizes our findings on the outsized role intermediaries play in orchestrating the lifecycle of municipal digital infrastructure. Our focus is on the leverage points where opportunities exist for collective action by municipalities, intermediaries, and their funders to build on the accomplishments and learnings to date.

1 Governing

Governance consists of the decisions and actions of people who run a government, business, or organization. Municipal governance is highly complex. Elected officials, professional administrators, advisory groups, and even the courts all participate in direct and indirect ways. Technological systems also are developed and deployed within these governance systems, changing where, why and to whom information flows over time and the power it delivers.

Municipal digital infrastructure projects both shape, and are shaped by, existing systems of governance in cities. But they also must solve their own governance challenges, creating structures that allow them to collaborate closely, often over long periods of time and over great distance, on highly complex tasks. Unlike many open source projects, where contributors may hold fluid roles, as CitySDK project manager Hanna Niemi-Hugaerts explains, "It's nice that it's open source, but it's wrong to assume that someone has the time to both contribute to code and run the project at the same

time. You have to be clear on how the governing model should work." That includes, at a minimum, "establishing a product owner and creating maintenance specifications."

Beyond that first baby step towards clearer governance, our research identified four main governance functions that successful municipal digital infrastructure initiatives perform.

Shared purpose and context

Modern software development is a fluid process, adapting to a constantly evolving set of needs, capabilities and constraints. While this flexibility makes it possible for cities on opposite sides of the planet to collaborate on production, a deeper shared purpose and context is key to success.

In our case studies, nationality was the most important shared context. Municipalities in the same country typically share a similar set of responsibilities and resources. Will Callaghan, Product and Project Lead for LocalGov Drupal, estimates user needs differ by less than 10 percent between the UK councils the group works with. The Foundation for Public Code works exclusively with Dutch municipalities, through a partnership with a national municipal organization. In Denmark, OS2 is directly funded and coordinated by the central government.

Some municipal digital infrastructure projects do span national boundaries. But these projects built on existing multilateral partnerships in the Nordic countries and the European Community.

Representative leadership and realistic priorities

Municipal digital infrastructure initiatives must address a shared set of problems. Deciding who gets to define this shared agenda, and how, is the most important decision new collaborations must make.

Some intermediaries establish formal processes for choosing leaders and setting processes. Denmark's OS2 uses a steering committee consisting of stakeholders from the most active municipalities to pick projects

for the broader group. Each project then establishes its own governance model, picking a lead municipality to manage the project, and pooling resources to staff that role. In larger collaborations with a dozen or more municipalities, a steering committee of 3 or 4 municipalities may govern on behalf of the entire group to create a more manageable structure. LocalGov Drupal uses what Callaghan calls "sociocratic structures", ad hoc project-based working groups drawing on participating municipalities that further self-organize into product and technical committees.

Policy advocacy and regulatory support

Every intermediary organization we studied identified the critical importance of having a champion in government. As "boundary spanners", these champions are more than just cheerleaders who garner support for projects. They update regulation, propose policy changes, and fundraise for partners in government and intermediaries.

Advocacy efforts also work by building broad bases of support, linking up across multiple municipalities and leverage national and supranational government bodies. In 2018, for instance, the UK Ministry of Housing, Communities and Local Government (now the Ministry of Housing, Communities and Levelling Up) issued a "Local Digital Declaration" co-signed by 45 local authorities, sector bodies and government departments that laid out "a shared ambition for the future of local public services" including specific goals and commitments.

Intermediaries themselves can also be a powerful force for policy advocacy. For instance, in Denmark, OS2 carries out strategic communications efforts aimed at improving understanding and promoting open source among policymakers and elected officials.

Continuity over time

Changes in municipal or national political leadership can destabilize and even destroy municipal digital infrastructure projects. Intermediaries can provide a powerful tool for sustaining efforts across changes in administrations and personnel. The Foundation for Public Code, which originally saw its primary role

as providing technical governance over shared code-bases, has found that there is demand for financial and organizational stewardship to sustain collaborations as well—because partners want to make sure that projects don't depend on a single lead municipality for long-term survival. The goal is to avoid a situation where, as Ben Cerveny puts it, "the municipality or the state might say 'we're cutting funding unless you do this'", and try to impose its agenda on the group.

Intermediaries can also deliver geopolitical resilience. Because CitySDK open sourced its outputs, developers in Istanbul were able to continue knowledge-sharing and collaboration with partners in Amsterdam during a turbulent political period in Turkey. X-Road software has been deployed in Ukraine and Kurdistan, and the project's broader community "has been a platform for disseminating the entire bundle of computer code and regulatory code for public sector restructuring", according to Petteri Kivimäki, the project's Chief Technology Officer.

2 Producing

Traditionally, most open source projects focus the majority of effort and resources on the production of new computer code. But production doesn't dominate municipal digital infrastructure efforts in the same way. As we have already seen, significant time and energy goes into governing these collaborations. (And in the next two sections, we will see how resources must also be shared with implementation and learning activities.) Nonetheless, production of code is a vital foundation for municipal digital infrastructure. Our research identifies two essential steps that are key to success—defining outcomes for users, and encouraging and incentivizing contributions.

Defining outcomes for users

Often in commercial software development, a focus on user needs provides clarity about desired outcomes. Many open source efforts lack the same intent or ability. Often outcomes are set in a more ad hoc, arbitrary way based on the views of a core group of developers. These desired outcomes may prioritize technical innovations that overlook or even work against user

needs. As LocalGov Drupal's Will Callaghan explains, "there are too many projects where products are not tested until the end. And then they realize, 'why did we even do this? It doesn't satisfy anyone's needs.'"

In orchestrated development, intermediaries work to make sure user needs come first. For instance, LocalGov Drupal facilitates design sprints before any coding begins, to surface user needs. For OpenTripPlanner, this meant involving subject matter experts early on to shape the use case, explains project lead Kevin Webb. That involved doing hackathons with university partners, but also focused efforts to push project owners in government to prioritize and strategize around user acquisition, an often-overlooked task.

Incentivizing and facilitating contributions

While users come first in orchestrated development, developers need incentives and tools for contribution to collaborative code. Open source licenses are an important tool for incentivizing contribution, by requiring attribution while also making it easy to reuse code. The X-Road project uses the MIT license, a short and permissive framework that does not affect derivative works. That makes it easier for others to copy, adapt, and improve upon code in government or commercial uses.

Modern software development practices make it easier to mobilize and maximize the value of code contributions. LocalGov Drupal serves as a product manager, facilitating 1- and 2-week code development sprints based on the Scrum methodology. The Foundation for Public Code identifies opportunities for code modularization and customization, for instance, which seeks to simplify and speed the reuse of code by different users and in different contexts. CitySDK focused on implementation standards, including the vital preliminary step of convincing stakeholders of the value of standardization. Job Spierings, who led Amsterdam's CitySDK pilot, says that building a narrative about the value of standards for municipal digital infrastructure among policymakers in participating cities was a major outcome of that project.

3 Implementing

Innovation has little value if it isn't put to use. Orchestrated development places heavy focus on implementation. Our discussions with intermediaries and their municipal stakeholders revealed two crucial strategies for implementation—curating vendor ecosystems, and upholding commitments to maintain. These strategies directly attack key obstacles to municipal digital infrastructure: trust and reliability.

Curated vendor ecosystems

Very little municipal digital infrastructure is produced by city governments directly. Most is produced by vendors under contract. But finding the right partner is hard. Some cities already have a strong technology partner who knows open source. Intermediaries often have a limited internal software engineering capacity as well. But these situations are unusual.

Over and over in our conversations with intermediaries, we heard about the need for curating vendor ecosystems, to help cities secure the technical capabilities to produce and implement municipal digital infrastructure. For instance:

- Denmark's OS2 maintains a list of more than 67 pre-screened vendors that have worked with municipalities on open source or demonstrated a high level of commitment and competence in open source technologies. According to OS2 head Rasmus Frey, working within this ecosystem of vendors ensures that "there's always at least one vendor adding to the codebase, they are getting paid to help us monitor for security issues, and that can help if we need new functionality." It also provides redundancy, allowing municipalities to change vendors much more easily if needed.

- X-Road's Technology Partners Program was launched after repeated requests from participating governments for referrals. Vendors are classified in a three-level system based on experience with the project code: active contributors; those that have completed at least one deployment; and those who have integrated other services with X-Road.

- In the UK, LocalGov Drupal is also building a tiered list of accredited suppliers. The group's approach is to monitor shared codebases for pull requests and other contributions to identify vendors it will invite to participate.

- During the development of CitySDK's Mobility API, the partner city, Amsterdam, did not have the technical capacity within city government to develop the system. For the local intermediary (Waag Futurelab), project manager Job Spierings involved local developers and curated a network of vendors and non-profits who were essential in building the API.

There are many benefits to pairing cities with trusted firms. For municipalities, it creates an opportunity to address some structural problems with existing procurement processes—they can be slow, put too much emphasis on cost over other criteria, and can disadvantage small and minority-owned businesses. It's also notoriously difficult for groups of municipalities to coordinate procurements.

For intermediaries, working with pre-screened vendors offloads the heavy lifting of implementation, freeing up resources to focus on governance and learning activities, with less risk. It also streamlines the relationship between intermediaries and municipalities, because there's no real exchange of goods and services. LocalGov Drupal, for instance, only asks councils to sign a simple memorandum of understanding. "You don't need to pay us anything. And likewise, we're not going to pay you anything," explains Will Callaghan of LocalGov Drupal. "This is not a service level agreement. You have no obligation to us. And you can cancel anytime you want."

In some countries, intermediaries can leverage national open source procurement efforts to build vendor ecosystems. The UK's Digital Marketplace provides an open, transparent platform for procurement, where municipalities can post tenders to a network of pre-qualified suppliers. Many European countries have established similar "digital transformation" groups, and designated open source procurement officers. As Ben Cerveny of Foundation for Public Code explains, "Those offices are specifically tasked with understanding the savings and value add of working in open source. And so they now often are the attach point for our organization."

Commitment to maintain

All too often, sustained effort in open source projects ends with initial deployment. As Cornell Tech- Jacobs Urban Tech fellow Rasmi Elasmar notes, "This is a huge challenge especially when compared to software-as-a-service (SaaS) procurement. The code may be free, but who pays for the infrastructure it is deployed on, the ongoing software development, the security and site reliability staff to keep it running smoothly? These are necessary costs but are difficult to assess and manage in a unified way. In SaaS, this is all rolled into one fee/contract. In OSS, if you don't have these capabilities in-house, you need to procure them piecemeal and often over a long timeline."

Since open source is often selected as a low-cost alternative, insufficient resources are devoted to ongoing monitoring and updating. For OpenTripPlanner lead Kevin Webb, the "operational infrastructure" of these projects is more than just code—it includes data pipelines and digital services that must be delivered, maintained, and improved over time—but the open, collaborative structure of orchestrated development often makes this challenging. Responsibility for maintaining software and digital services is often unclear. Finally, many municipal digital infrastructure projects are pilots or prototypes, further reducing incentive to maintain.

Intermediaries employ a variety of tools to clarify, prioritize, and direct resources to maintenance. CitySDK developed a formal "Letter of Commitment" which obligated city partners to maintain a deployed service for two years. X-Road provides product support, but emphasizes self-study, and facilitates referrals to outside vendors and volunteer mentors. OS2 sees maintenance as a critical activity to the long-term success of the organization, "We make sure that this product organization is maintained, because people will come and go, organizations will come and go in this. So we have to make sure that it doesn't die out".

One promising development are new approaches to software lifecycle management (SLM), which formalizes "coordinating activities and managing resources (e.g. people, money, documentation, technical artifacts) during the entire lifecycle of a software product, from initial ideation to retirement." These efforts adapt

industry best practices to the unique constraints of public sector organizations working with open source ecosystems. The community-based software lifecycle management model developed in Finland, devotes two dedicated, jointly-financed personnel roles—a product manager maintains contributions to a shared, integrated, open source code base; and a community manager who deals with governance, to ensure the openness and inclusiveness of the development process. In a project that developed and maintained an open source browser tool, the National Land Survey, this approach resulted in software that had fewer bugs, better documentation and peer support, and was more extensible. Donor and developer bases were more diversified, reducing the risk of exit of any one contributor, and because the software was more attractive to new users it was easier to grow the community, develop credibility, and attract resources to become financially sustainable.

4 Learning

Documentation and training are often overlooked in open source software projects. For municipal digital infrastructure, they may be the first tasks to be curtailed or cut in a budget crunch or when working against a deadline. But these activities play a crucial role in orchestrated development, sustaining and amplifying investments in governance, production, and implementation.

As we discovered, this leverage is why intermediaries devote disproportionate resources to learning. They create and disseminate documentation, and many provide formal training. The Nordic Institute for Interoperability Solutions' runs the X-Road Academy, for instance, in which it partners with university-based experts to deliver online training. Foundation for Public Code offers an 18-part "Standard for Public Code" course that teaches software development and maintenance approaches that can reduce cost and risk in collaborative municipal digital infrastructure efforts.

But intermediaries also invest in two more ambitious and impactful kinds of learning: nurturing support communities, and capturing tacit knowledge.

Nurturing support communities

The rise of social media profoundly changed the way people seek and obtain technical support for both simple and complex problems. Discussion forums, chatrooms, and Q&A sites provide places where users can support each other, with or without the participation of software producers. A variety of reputation systems, such as the one used on the popular Stack-Overflow coding Q&A site, help people seeking answers and advice to evaluate the quality of information they find.

Many of these practices were themselves pioneered by open source developers. And thus it is not surprising that intermediaries are developing their own support communities. For now, these support communities tend to be more intimate and informal, due to the small number of stakeholders involved. In lieu of formal support, X-Road, for instance, maintains several online forums that bring together coders who have contributed to the software, organizations that have deployed it, and companies that integrate with digital services powered by X-Road deployments. The group gathers annually for a virtual conference that attracts up to 300 members of this extended community.

Capturing tacit knowledge

As we have seen, computer code isn't the only thing that matters in orchestrated development. And it's no longer even the only kind of "code". Intermediaries like Ben Cerveny at Foundation for Public Code see opportunities to formalize and standardize complex design patterns for municipal digital infrastructure into documentation he calls "process code".

Process code does two things. First, it pulls together information needed to achieve a complex task in a standardized way. For example, establishing a cloud computing service that allows participating municipalities to deploy containerized software might involve many different technologies, vendors, and services. More important is the second function of process code, which does the hard work of organizing that information in a way that's tailored to the needs of stakeholders in municipal digital infrastructure projects.

Imagine, Cerveny asks, a city that wants "to build an authentication system for departments to work with other back-end services?" Or a consortium of municipalities that wants to create its own cloud service for cities to deploy containerized services? The best answers to these questions are still stuck in the heads of those who've solved them before. The potential of process code is in extracting that tacit knowledge and writing it down. Process code doesn't have to be followed—it may be most useful, Cerveny argues, in giving cities the confidence to engage a consultant with a much clearer sense of the benefits and risks, and assets and methods involved.

How do we move forward?

Intermediaries play a pivotal and indispensable role in orchestrated development. This linked set of processes for governing, producing, implementing, and improving open source software provides the structure for municipal digital infrastructure to thrive.

In this final section, we highlight three strategic challenges for municipal digital infrastructure going forward.

Sparking deals with establishing guiding principles and setting goals.

Scaling involves putting innovations into practice for meaningful objectives that substantially serve those in need.

Sustaining is about creating the institutional pillars of support—financial, policy, and technical infrastructure—that ensures municipal digital infrastructure evolves, performs, and persists over time.

For each challenge, we identify which stakeholders are best suited to lead. While intermediaries are the conductors of orchestrated development, they can't do it alone. The active participation of other stakeholders is essential for success. Cities must play a leadership role in *sparking*, by setting priorities and defining prob-lems. And in almost every case, external funders must step in to provide resources for *sustaining* municipal digital infrastructure, to create the basic capacity for collaboration. The relevant capacities and resources of each stakeholder group and appropriate leadership roles are summarized in Table 2.

Sparking: the catalytic role of municipal leaders

Sparking deals with establishing guiding principles and setting goals for each step in the orchestrated development cycle—governance, production, implementation, and learning. Municipal leaders must lead here, and three strategies hold the greatest potential for impactful and meaningful progress.

Empower "boundary spanners"

"Boundary spanners" are individuals who connect their organization with external sources of knowledge. Boundary spanners are knowledgeable about the technical and business benefits of open source software and become key advocates, advancing initiatives from the bottom-up. Research has shown that the degree of municipal digital infrastructure adoption depends on the presence of boundary spanners—and the presence of boundary spanners matters more than other factors like financial stress and city size. "The adoption of [municipal digital infrastructure] depends less on the

Table 2. Leadership Framework for Orchestrated Development

	Municipal Governments	Intermediaries	Funders
Strengths	• Identify user needs, as well as develop opportunities to implement digital solutions • Initiating and implementing software development, while upskilling their technical capacity with the help of intermediaries	• Connecting municipalities that may be interested in solving similar problems, as well as pooling together resources from across various municipalities to implement a project • Provides project management services that contribute to sustainable product development	• Convening authority to create issue networks and campaigns • Can rapidly direct resources to municipal governments and intermediaries • Can sustain support over longer periods of time • Can mobilize others to deliver resources and expertise
Challenges	• Having limited resources to support in-house expertise or budgets that support software maintenance • Vendor lock-in from expensive or opaque proprietary software • Lack of product longevity due to limited funding and in-house expertise	• Lack of product longevity due to limited funding • Lack of policies that support procuring and developing open source software • More resources needed to provide more process documentation, known as "process code"	• Lack legitimacy on their own—this must be granted by municipal innovators • Shifting priorities based on organizational needs
Strategies	Ways to **spark** the orchestrated development process: • Empower "boundary spanners" • Be a user advocate • Be strategic about procurement	Ways to **scale** the orchestrated development process: • Expand and govern project ecosystems • Document the process, not just the code • Quantify the contributions of vendors • Source new ideas, especially from users and product owners	Ways to **sustain** the orchestrated development process: • Establish an "intermediary of intermediaries" to cross-pollinate knowledge and replicate successful models globally • Provide bridge funding for intermediaries in years 3 through 5

> **"The biggest obstacle to municipal digital infrastructure are cities' own rules for buying software and services."**

broader economic and social context but more on the particular confluence of personal and political support for OSS within the organization".[1]

We saw two styles of boundary spanning in the municipal digital infrastructure projects we studied.

The first type is product-focused. This typically involves developing a strong technical vision and shipping a digital solution. For instance, Portland's regional transit agency TriMet had a technically sophisticated information technology department that led the technical vision of Open Trip Planner, according to Open Plans' Kevin Webb.

The second style of boundary spanning emphasizes process, and focuses on developing standards and protocols to encourage municipal departments to adopt best practices. Often, this approach is influenced or implemented by national or subnational levels of government working with or on behalf of municipalities. The UK's 2018 Local Digital Declaration created a need for an intermediary like LocalGov Drupal to help local governments adopt best open source practices.

At the national level, digital services or digital innovation teams function as highly effective boundary spanners. However, these teams either do not exist or are not as well-developed at the municipal level.

A growing number of municipalities have formalized boundary-spanning roles through the creation of positions such as Chief Technology Officer or Chief Innovation Officer. Initially, these boundary spanner(s) may operate in isolation. Over time, however, these leaders are able to share their knowledge and train peers to share the roles of boundary spanning. This process works best when leaders grant permission and create incentives to staff who can identify needs and opportunities for municipal digital infrastructure, and initiate projects.[2]

Advocate for marginalized users

The pace of digitalization and the steep demands digital services place on users make it easy to leave marginalized groups behind. Municipal governments must play a leading role in demanding robust user research, participate in these efforts, and verify that findings are incorporated into orchestrated development processes. This may include working closely with intermediaries to design and conduct more specific user research engagements, such as detailed user personas, focus groups/interviews, and A/B testing.

User research provides a number of benefits. It is essential in validating any assumptions about the scope and usability of a digital solution. Testing early and often helps avoid any inefficiencies and unnecessary parts of the product, and helps build trust between the producers and consumers of software.

City leaders can also play a crucial role in user advocacy simply by driving interest and traffic to services delivered by municipal digital infrastructure. As Kevin Webb explains, in the private sector user acquisition costs are very high. If it's difficult for the private sector to acquire users, municipal digital infrastructure advocates need to have realistic expectations about their ability to attract users and devote proportionate resources to building a user base and community. However, the government also has a monopoly on many digital services. This can make it easy to capture users, but make it harder to identify usability challenges since people have no other choice. Tools such as Code for America's National Safety Net Scorecard, however, show how accountability standards can hold municipal digital services (and the municipal digital infrastructure that underpins them) to a high standard of excellence.

1   Alexander van Loon and Dimiter Toshkov, "Adopting open source software in public administration: The importance of boundary spanners and political commitment," Government Information Quarterly, 32, no. 2 (2015): 207-215. https://doi.org/10.1016/j.giq.2015.01.004.

2   Benjamin Edwards, Solomon Greene, and G. Thomas Kingsley, *A Political Economy Framework for the Urban Data Revolution*, (Washington, DC: Urban Institute, 2016), https://www.urban.org/research/publication/political-economy-framework-urban-data-revolution.

Make procurement competitive for open source

The biggest obstacle to municipal digital infrastructure are cities' own rules for buying software and services. For instance, while procurement actually brings a welcome level of up-front rigor to defining roles and outcomes in open source efforts, it often creates requirements for intermediaries and open source vendors that block them or make them non-competitive.

Yet simply changing the rules isn't enough. "Even when municipal procurement policy requires open source software to receive equal consideration, fair competition is not assured." A 2010 study to assess the impact of a Dutch policy favoring open source after three years in force found that "even when municipal procurement policy requires open source software to receive equal consideration, fair competition is not assured...in over forty-five percent of tenders, free software was not given an equal chance to win the bid."[3]

One approach to improve outcomes is more rigor in quantifying the contributions of vendors. Metrics that could include the number and frequency of vendors' pull requests to key open source code bases; participation in technical group conversations; and overall quality of code work.

Another potentially transformative idea is to require a share of the code produced through procurements be released as open source. For instance, in 2016, the U.S. federal government adopted a new source code policy that established a pilot program requiring agencies to release at least 20 percent of all custom-developed code as open source software for three years.[4]

More strategically, municipalities that want to embrace open source need to invest more in internal capacity for managing software outsourcing. For instance, Amsterdam established its Data Lab after the conclu-

sion of its CitySDK pilot. As project manager Job Spierings explained, CitySDK "found fertile ground with a group of policymakers" who realized that capacity was needed inside the government. Just as the city's transport department doesn't build roads, but knows enough about how to make roads to hire a good contractor, cities need technical staff that know how to make the most of intermediaries. These personnel will be better equipped to evaluate the full value of working with vendors who deliver open source solutions.
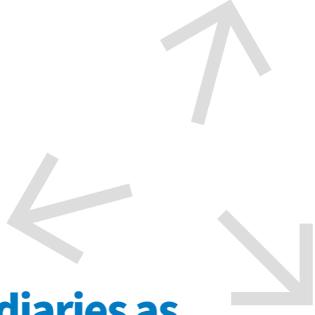
Scaling: intermediaries as resourceful connectors

Scaling involves packaging successful prototypes into products and services that serve meaningful numbers of people in need. Intermediaries play the most important role here. As *resourceful connectors*, intermediaries identify and engage all of the stakeholders who deliver the services and knowledge that make it possible to expand the use and utility of municipal digital infrastructure. Three strategies can strengthen this role.

Secure project governance

Creating durable scale for municipal digital infrastructure projects requires more than clever engineering and the cloud. Governance mechanisms are needed to ensure the long-term effectiveness and survivability of the collaborations created by producing and implementing code. Intermediaries can provide a "safe haven" for other stakeholders to coordinate efforts and steer the development of software projects, free of the constraints of their own organizations. This collaboration builds trust, improves accountability, and extends the longevity of the orchestrated development process.

All of these strengths are essential to neutralizing conflict. As Foundation for Public Code's Ben Cerveny

3   Mathieu Paapst, "Affirmative Action in Procurement for Open Standards and FLOSS", *International Free and Open Source Software Law Review* 181 (2010); in Collanino, 925.

4   Tony Scott and Anne E. Rung, "Federal Source Code Policy: Achieving Efficiency, Transparency, and Innovation through Reusable and Open Source Software," (Washington, DC: Executive Office of the President, Office of Management and Budget, August 8, 2016), https://obamawhitehouse.archives.gov/sites/default/files/omb/memoranda/2016/m_16_21.pdf.

explains, "building a governance model that exists in an independent organization is often one of the first steps to getting to replication, because a lot of times, other municipalities and states don't want to implement codebases that are [controlled by another government]. They want to be part of a process of deciding, so in order to make the decision, you need to come up with both the governance model". In the broader digital infrastructure universe, this role is filled by organizations such as the Apache Software Foundation. Intermediaries are beginning to fill this role for municipal digital infrastructure, but it could be strengthened.

Write down the process, not just the code

In traditional open source development, knowledge between contributors may become lost over time. Documentation is incomplete and becomes quickly outdated. But even the best open source projects often omit important knowledge about the code of how code gets made, deployed, and used. Embedding "process code" as a best practice mitigates information loss and captures tacit knowledge in an easily usable form, which can then be used to repeat tasks in a standardized way.

Documenting process code has other benefits from simply accelerating and improving the quality of knowledge transfer. Collecting this resource can help municipalities to feel informed and empowered when making technical decisions. And it can reveal inefficiencies in municipal technology practices. For example, when developing process code for CitySDK, Hana Niemi-Hugaerts explained that documenting the data protocol for the CitySDK API surfaced redundant data collection and inconsistent data variable names. Identifying these weaknesses became an opportunity for developing formal ontologies and metadata, and reducing data duplication for Helsinki.

Process documentation is essential, but it is costly to produce. The biggest challenges that intermediaries face are the amount of resources needed to maintain and create outreach and process documentation. Although some intermediaries may have structural funding mechanisms, limited budgets constrain intermediaries from hiring more staff or bill time to generate process codebases. Also, if municipalities have to reduce

their budget for intermediaries, process documentation tends to be one of the first responsibilities to be threatened or negated.

Quantify the contributions of vendors

Intermediaries are critical in linking municipalities with a vetted network of open source vendors that can augment governments' own internal engineering capabilities. Most of the intermediaries we studied developed formal efforts to curate and credential lists of preferred vendors for their municipal partners. These vetted networks help municipalities easily find bespoke and trusted talent to fill their technology resource needs.

Some level of quantitative rigor makes these referral systems much more effective. Some of the metrics that intermediaries use include the number and frequency of vendors' pull requests to key open source code bases; participation in technical group conversations; and overall quality of code work.

Source new ideas

Every organization we interviewed expressed a desire to expand contributions to their codebase, especially beyond their core developer teams. The motivation was not simply sourcing volunteers, but most importantly, opening the door for new ideas and problem-solving approaches. But for intermediaries to expand contributions to their codebase, they need to develop focused creative strategies that encourage contributions. As OpenTripPlanner's Kevin Webb laments, it is "naive to think coders will come".

Lowering barriers to participation is a good starting point. One widely-used approach in open source communities is to decompose projects into smaller pieces. These efforts can often be decoupled from larger development paths, and create more flexibility for people and groups with different capabilities to contribute. In practice, this can mean tagging issues for different levels of experience, skills, or problem type; as well as refactoring large, integrated codebases into smaller, but interoperable functions. As a side benefit, this modularity can improve prospects for reuse, scaling, and impact.

Intermediaries can also harness their convening power for more fundamental contributions to product vision and design. As Ville Sirviö from NIIS stated, "having active and [diverse] community members means community members around the world could have a say on what they would like to see being developed. Increas[ing] the number of people involved in the development and getting different views from different countries, different backgrounds, and different technical knowledge or skills, [helps our products and ideas evolve]".

Sustaining: campaigns that fill capacity gaps

Sustaining deals with the institutional pillars of support—financial, policy, and technical infrastructure—can ensure municipal digital infrastructure evolves, performs and persists over time. We see a major role for the philanthropic community in consolidating the successes of municipal digital infrastructure stakeholders to date and creating platforms for greater future impact.

Establish an "intermediary of intermediaries"

Each of the organizations we studied either is, or is on the way to becoming, the dominant intermediary fostering municipal infrastructure in their respective nation. However, we also found little evidence that these organizations are fully aware of, or actively engaged in substantive and ongoing dialogue and exchange with each other. As a result, successful ideas and practices are not being systematically cross-fertilized and opportunities for collective action are not being identified or pursued.

A new organization serving as an "intermediary of intermediaries" could help close this gap. Some possible functions of this entity could include:

- Development and dissemination of best practices documents.

- Design and delivery of training for intermediary personnel.

- Organize convenings to strengthen professional and social networks within the municipal digital infrastructure community.

- Formulate model policies that expand the use of open source software in municipal governments.

An existing organization that could provide a model, or take on this function as a project, is the Intergovernmental Software Collaborative at Georgetown University's Beeck Center for Social Impact and Innovation.[5] Another potential vehicle is the World Economic Forum's G20 Global Smart Cities Alliance, which has positioned itself as an urban technology equivalent of the highly successful C40 Cities Climate Leadership Group, which over the last 17 years has coordinated policy and action across a global network of large cities.

Mobilize bridge funding

All of the intermediary organizations we studied are, or will soon be, struggling to secure sustainable long-term funding for their activities. This is due to a structural gap in financing tools currently available.

The majority of intermediaries we studied were established with funding from national governments and multilateral organizations. The motivation is fiscal prudence. Cerveny explains, "national governments or supranational governments, like the European Commission are much more likely to understand how much redundancy there is and how much cheaper it would be to have an open source product, rather than 4000 instances of SAP across all of our municipalities."

These programs, however, are focused on short-term results in the form of cost savings for the government. Bootstrapping municipal digital infrastructure

5   "Intergovernmental Software Collaborative," Website, accessed November 11, 2022, https://beeckcenter.georgetown.edu/projects/intergovernmental-software-collaborative/.

campaigns involves significant up-front costs and time investment by intermediaries to develop activities that support all four processes of orchestrated development—governing, producing, implementing, and learning. As Will Callaghan of Local Gov Drupal explains, "It's been stressful to get a really short runway. It's hard to crack these problems on a stopwatch." There are exceptions, like France's Beta.Gouv, where money is specifically allocated for early development and risk-taking in digital services, but this is the exception. In most places, short-termism results in less, more incremental innovation that reaches fewer municipalities.

Funders can provide a bridge that gives intermediaries more time and greater flexibility to secure their organization's future revenue streams. Typically, this gap opens up in years 3 through 5, when launch funding runs out but a long-term sustainable business model has not been fully developed.

Related to this, funders can also intervene to fund elements of orchestrated development that are essential, but often undervalued. Documenting tacit knowledge or updating security and code quality are critical responsibilities, but also the most under threat when faced with budget cuts. Without these vital, yet labor-intensive, tasks, the stability of municipal digital infrastructure is compromised.

Questions for the future

This project identified a subset of digital infrastructure—*municipal digital infrastructure*—that is produced by collaborations between city governments. This work is organized by a class of NGOs we call *intermediaries* who define and coordinate a seemingly unstructured set of activities into four distinct processes of governance, production, implementation, and learning. We use the term *orchestrated development* to describe this larger managed lifecycle approach to municipal digital infrastructure.

The value of this approach is two-fold. First it gives us an analytic framework, including vocabulary, to identify and isolate specific stakeholders and activities, so that we can start to identify what works and where there are gaps. Most importantly, it highlights the indispensable role played by intermediaries. Above,

we have identified nearly a dozen strategies by which municipalities, intermediaries, and funders (including but not limited to philanthropies) can concentrate efforts and investments that will bolster the capacity and effectiveness of the networks intermediaries have already established.

However, at the end of this investigation, we find ourselves with more open questions than answers. We share these to provide starting points for future research and strategy formation.

- What other stakeholders remain unaware or excluded from current practices of orchestrated development? How could they be identified and engaged?

- Where are intermediaries most effective and where are they least effective? What other functions should intermediaries take on? Which functions could they delegate more effectively to others?

- How big is the learning gap between what should be captured and shared in orchestrated development processes, and what actually is? What are the most effective ways to fill this gap?

- What changes do municipalities need to make—to policy, regulation, infrastructure, and talent—to make better use of intermediaries? More fundamentally, are intermediaries always the right tool, or does their existence reflect structural shortcomings in government capacity? How does the answer to that change in different local and national contexts?

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About the Urban Tech Hub

The Jacobs Urban Tech Hub at Cornell Tech is a new academic center in New York City that generates applied research, fosters an expanding tech ecosystem, and cultivates a new generation of urban technology leaders. We bring a human-centered approach to research and education with the aim of building a better world through increased access and opportunity within the technology sector.

Based at the Jacobs Technion-Cornell Institute at Cornell Tech, the Urban Tech Hub leverages the resources of Cornell University and brings together researchers, engineers, scientists, urban tech companies, government agencies, and community organizations to address the challenges facing cities today.

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