CITIZEN URBAN SCIENCE

New Partnerships for Advancing Knowledge

Anthony Townsend and Alissa Chisholm

Cities of Data Project
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Over the coming decades, the world will continue to urbanize rapidly amidst an historic migration of computing power off the desktop, unleashing new opportunities for data collection that reveal how cities function. In a recent report, *Making Sense of the Science of Cities* (bit.ly/sciencecities) we described an emerging global research movement that seeks establish a *new urban science* built atop this new infrastructure of instruments.[1] But will this new intellectual venture be an inclusive endeavor? What role is there for the growing ranks of increasingly well-equipped and well-informed citizen volunteers and amateur investigators to work alongside professional scientists? How are researchers, activists and city governments exploring that potential today? Finally, what can be done to encourage and accelerate experimentation?

This report examines three case studies that provide insight into emerging models of citizen science, highlighting the possibilities of citizen-university-government collaborative research, and the important role of open data platforms to enable these partnerships.

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The Potential of Citizen Urban Science

Universities around the world are bringing online a massive new infrastructure for data-driven urban research in the coming decades — an investment which could surpass $2.5 billion by 2030. But while there is much talk of the importance of citizens in these efforts as beneficiaries of research effort, their envisioned role in the research process is much less clear. Predominantly, these efforts envision future urban research as a tripartite collaboration of university, city government and private sector firms. The 'new urban science', as many are calling this movement, has not yet defined how it intends to engage or empower non-professionals in the research process — a glaring omission in an age where new digital platforms are unleashing the power of mass participation in so many other areas of the economy, governance, and intellectual and political life.

Citizen science has thrived in recent years as these changes have unfolded. While amateurs have long played important roles in many fields, from astronomy to meteorology, the web has lowered the cost and expanded the range of collaborative activities with professional scientists. For instance, amateurs now routinely participate not only in the analysis of large data sets, but in so doing help train computer software to perform the same tasks. There is so much citizen science happening now, that the practice itself is becoming a field of academic inquiry itself - in early 2015 the prestigious journal *Bioscience* called for the recognition of "research on citizen science as a distinct discipline".

The Benefits of Citizen Urban Science

Urban science is emerging, changing and evolving — but its relationship with citizen science will inevitably become deeply complex and multi-faceted, and controversial. That's because not only is citizen science a necessary key to improving the science of cities, it is a tool for making the case that the results of such research are to be trusted when applied in urban governance. Citizen science can provide the ground truth necessary to trust the synoptic urban sensing tools being used in urban science. Our operating hypothesis then is that citizen urban science will become an increasingly important strategy within the urban science movement:

-- For doing better science – by creating larger and more detailed data sets;

-- For making the pursuit of science less technocratic – by giving citizens a stake in data gathering, analysis, application of results, and even setting parts of the research agenda;

-- For applying new knowledge in the real world – by creating sustained engagement between researchers and partners in local governments for tech transfer.

Environmental Justice: Policy Implications of Citizen Urban Science

The successes of the environmental justice movement over the last half-century demonstrate the ways in which citizen urban science can have major lasting impacts on urban policy and planning, and the lives of people and groups in urban communities. Environmental justice itself grew directly out of the civil rights struggle — in 1968 Martin Luther King, Jr. fought on behalf of black sanitation workers in Memphis.[2] The environmental justice movement coalesced in the 1970s and 1980s through activist efforts, which focused attention on the systematic biases and shortcomings of environmental risk assessment practices in the United States — especially around urban air pollution impacts of siting decisions for highly noxious public facilities such as incinerators, trash transfer stations and waste treatment plants.

In the 1990s, the movement began to trigger reforms on urban environmental policy at the federal level. Robert Bullard's landmark report *Dumping in Dixie: Race, Class, and Environmental Quality* (1990) led directly to the Clinton administration's 1994 executive order (Executive Order 12898) mandating environmental justice reviews in the conduct of federal government operations.[3] But despite its origins in a movement based on its appeal of human rights, ethics and fairness, data and quantitative evidence has been critical to building support and a record of victories for the movement. Citizen- and activist-collected data have been used to win cases on the behalf of communities unfairly targeted as hosts for threats to public health such as nuclear waste disposal and industrial facilities.[4] Such data were used to contest the federal government's own assessment tools, which had become so institutionalized that their weaknesses were called an"open secret".[5]

While previously environmental justice had a contentious relationship with professional science — generally the movement viewed traditional science as cold and detached, and unwilling or unable to incorporate social factors into environmental hazard assessment,whereas the scientists saw environmental justice advocates as unorganized and emotional — the movement still wielded scientific data and methods to serve its own ends with great prowess and effectiveness. Evidence-based campaigns have been effective in policy circles at the federal level- bringing change to the ways the EPA conducts environmental

assessments as well as leading to the creation of the Office of Environmental Justice, these efforts still face adversity. Despite the massive amount of citizen-collected data the movement has produced, very little has been utilized in formal scientific research where it is still often viewed with extreme skepticism.[6]

A Spectrum of Citizen Urban Science

How is the opportunity for citizen urban science being explored today? In this section, we present three case studies of citizen urban science projects that represent a broad spectrum of models for bringing together citizens, academic researchers, and government agencies to do urban research. We focus in particular on the role of open data in each, how it mobilizes and catalyzes participation and trust, and how its role can be expanded and strengthened. Our cases include:

> Chicago's **Array of Things -** a large-scale urban environmental sensor network blanketing the downtown Loop, established to provide a testbed for university research and citizen engagement.
>
> Amsterdam's **Smart Citizens Lab** - a training and prototyping facility in Amsterdam that seeks to develop a corps of citizen scientists to deploy and maintain sensors throughout the city.
>
> New York City's **Trees Count!** - a crowdsourced effort to conduct a decennial census of street trees to support ongoing planning and operations, and potential future research.

The key criteria we used to select the case studies (summarized in the table below) include:

- Is the data collection fixed or mobile?
- Is the data being collected primarily for research or for operational planning purposes?
- Is the data collection a one-time, temporary, or ephemeral effort or is it ongoing?
- Is the data collection effort volunteer or professionally-staffed?
- Who is the principal agent of the project - a citizen group, a university, or government?

	Inquisitive	Celebrational	Functional
Project	Array of Things	Citizen Science Lab	Trees Count!
Location	Chicago	Amsterdam	New York
Principal Agent	University	Non-profit	Government
Geography	Fixed network	Fixed facility	Mobile
Time Frame	Permanent	Semi-permanent	Ephemeral
Primary purpose	Research	Engagement	Planning
Staffing & participation	Professional	Mixed professional & volunteer	Mostly Volunteer

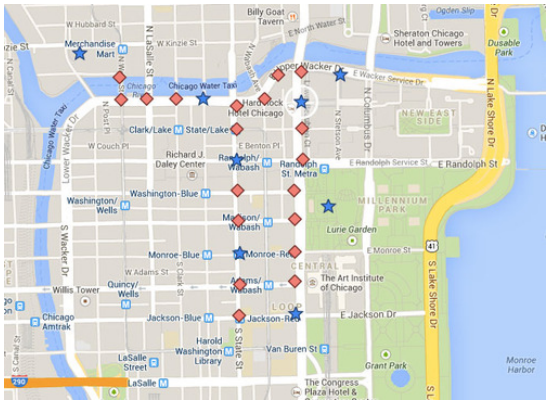
Array of Things

A project of the Urban Center for Computation Data, a partnership between the University of Chicago and Argonne National Laboratory, the Array of Things seeks to deploy "[a] network of interactive, modular sensor boxes around Chicago collecting real-time data on the city's environment, infrastructure, and activity for research and public use," according to the project's website.[7]

Describing itself as a "national monument", the project has high ambitions to create a public sensory infrastructure for urban research that supplies data for use in technology innovation, social science, and education. At the core of the project are multifunctional sensor pods that will initially measure temperature, humidity, light, CO. NO2, and vibration. Additional sensors under evaluation include volatile organic compounds (VOCs), O3, CO2, sulfur oxides, and particulate matter. In the future, more direct sensing of human activity is also contemplated through sound, infrared cameras and wireless network beacons to estimate pedestrian traffic. None of these sensors will collect or record any personal or identifying information. The project's researchers have gone to great pains to explain its activities in lay terms, describing it in one instance as "creating a fitness tracker for Chicago."

While a very top-down driven project coming out of a national laboratory and a major research university, it seeks to embody a more transparent and participatory research model. Among its stated goals are to "Make the data open to residents, software developers, scientists, and policy makers to encourage these groups to work together to make cities healthier, more livable, and more efficient." To this end, the team has also developed a next-generation data sharing platform (plenar.io) that will support distribution of large volumes of raw sensor data. All of the data produced will be published with multiple updates per minute- free- due to Chicago's established practice that data about the city is not monetized but provided

as a public utility. All software, hardware, parts, and specifications will be published as open source to encourage participation and oversight from the developer community and the public.



The project draws together a stunningly large network of collaborators, including the City of Chicago, Northern Illinois University, University of Illinois at Chicago, University of Illinois at Urbana-Champaign, DePaul University, Illinois Institute of Technology, Purdue University, University of Notre Dame, Arizona State University, the Santa Fe Institute, University College London, Clemson University, and the Institute for Advanced Architecture of Catalonia. Technical advice and support is provided by a number of companies including Cisco, Microsoft, Schneider Electric, Intel, Qualcomm, Motorola Solutions, and Zebra Technologies. Given the depth of knowledge and experience going into this project, these participants are positioning themselves to be at the forefront urban research grounded in data.

The first phase of nodes will be deployed around the supporting institutions (University of Chicago, School of the Art Institute Chicago, and Argonne National Laboratory).[8] Critical to the project's success is achieving manufacturing and deployment economies of scale. The first generation of devices were 3-d printed and hand-soldered. A second version was fabricated professionally, and a third version would be engineered into a smaller form factor and manufactured in large quantities locally at a price point of around $700, according to project director Charlie Catlett. As the number of devices begins to grow, Catlett hopes to distribute them to his peers at other urban universities in the US and Europe.

Array of Things is a highly supply-driven effort, assuming that users for the data will emerge from the research and citizen community. Some ideas the team has articulated include:

-- using sound and vibration to detect heavy vehicle traffic,

-- using infrared cameras to guide road salting in winter,

-- mapping micro-climates for block-by-block watering guidelines,

-- mapping pedestrian activity to time traffic lights and suggest late night routings.

Smart Citizens Lab

While Array of Things has focused on world-class engineering and development of formal partnerships with local government, the Amsterdam-based Waag Society is pursuing a more citizen-driven decentralized approach to instrumenting the city for urban science.

The Waag Society is a Dutch institute for art, science and technology established in Amsterdam over 20 years ago. Smart Citizens Lab was established in March 2015 but grew out of an earlier project, the 2014 Smart Citizen's Kit, which itself was a refinement of Waag's earlier collaboration on the Air Quality Egg with a global network. Led by public events coordinator Christine van den Horn, and researchers Frank Kresin and Pieter van Boheemen, the project aims to help "smart citizens" use open technology to increase engagement, share knowledge, and to build trust across communities and government institutions.

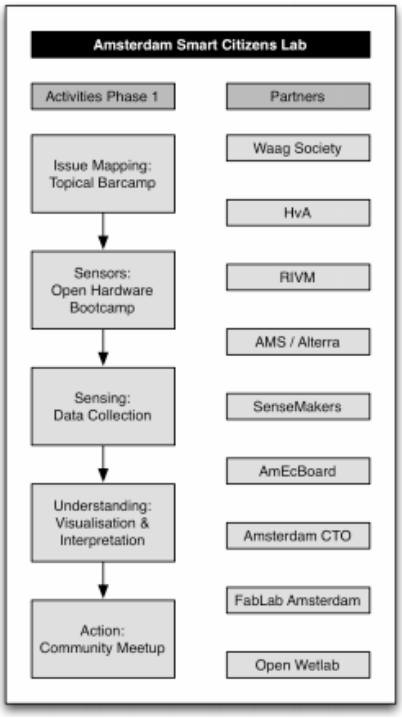
This effort is meant to help existing measurement bodies such as GGD Amsterdam and RIVM, the local and national health authorities, by extending their data gathering networks in an attempt to produce innovative solutions that can be scaled across Europe. There is a strong activist bent to the project, but at its heart is the belief that bottom-up data combined with data from official measurements networks will increase accuracy. The goal of the project is to establish a community that investigates and transforms the environment based on the data acquired by public sensor networks. Grounded by the belief that this will also lead to meaningful dialogues between citizens and governments, enhancing mutual understanding and cooperation

The genesis of the Smart Citizens Lab took form during the deployment of the Smart Citizens Kit, which was developed by Fab Lab Barcelona. In this effort, 100 citizens were equipped with low-cost open source sensor kits used to measure temperature, humidity, light, sound, CO, and NO2. Over 3 months the kits were used to measure environmental data. The community generated data was displayed on the Amsterdam City Dashboard (an online platform). This was done in conjunction with meetings hosted by Waag that informed participants about the hard and soft science of air quality measurements as well as the politics behind them. This effort resulted in a network of citizens and partner institutes with an enhanced understanding of the benefits and limitations of citizen collected data, leading to the creation of the Smart Citizens Laboratory.

The Amsterdam Smart Citizens Laboratory (ASCL) is meant to target communities of interest and communities of practice. Their activities consist of:

-- (Online) Community Building- through an open membership model facilitated through an online interactive platform.

-- Smart Citizen Events- which gather the community of practice and the community of interest with the aims of: meeting like-minded people, planning or joining actions/interventions, discussing community interests with several stakeholders (scientists, activist, policy makers, and hackers), present data to the community, discussing the interpretation and the impacts from interventions. These events also serve as a space to try out inexpensive tools and set the agenda for future activities.



-- Technology & Workshop Development- this effort is ran by two interns that will develop and test new and exciting Open Source hardware products as well as assisting community members in developing their own tools. These outcomes will be shared online through open platforms.

-- Fablab Open days & Open Wetlab Open Evenings- these are publicly announced and open days for community members to meet, learn, and exchange knowledge.

Complementing these efforts is Waag's focus on public outreach and efforts to build an identity for the ASCL community. These are undertaken in order to give members a sense of belonging and to strengthen the community, which will be cultivated through engagement activities and an emphasis that the events are critical part of the lab. Phase I is running March - November 2015, exploring the topics of air quality, water quality, and sound pollution. The project also relies on a network of partners including Gemeente Amsterdam (CTO), HvA, RIVM, SenseMakers, Alterra, AMS, Amsterdam Economic Board, Fablab Amsterdam, and the Open Wetlab. Internationally, key collaborators include Fablab Barcelona, Microgiants, FutureEverything, and Dundee University among others.

Trees Count!

The final case study from New York City illustrates a more functional form of data-gathering conducted in partnership on a one-off basis with volunteers in service of local government planning. Trees Count! is the latest in a series of arboreal censuses conducted by the city to identify and track the development of street trees as part of the city's sustainability planning.

These counts have a long modern legacy. The first small census took place in 1989 with about 80 volunteers, considered by organizers to be a "drive by" compared to the later efforts. By 1995, organizers pulled off the first "big" tree census undertaken by about 200 volunteers with the expressed goal of creating a data base to help the parks department maintain and plan for the city's trees.[9] This census was also initiated in an effort to better understand the life cycles of trees in the city. The next count, in support of the city's massive PlaNYC sustainability planning effort was conducted in 2005-2006, involving about 1,100 volunteers who counted 592,130 trees- a 19% increase from the previous census. Technologies such as geographic information systems and handheld computers were used to help enter and sort the data. Applying ecological economics principles, the city calculated ecosystem services worth $122 million from the trees.[10]

Collecting street data is valuable for many reasons. The information can aide in daily and strategic decision-making for management purposes and city planning. By tracking the changes in the urban landscape, the data can be used to estimate future needs and the trends in tree life cycles. The data has also been used for education purposes- helping citizens learn the importance of trees in urban life and their ability to make communities healthier and better places to live and work. Additionally, the benefits provided by the city's trees have now been quantified in terms of the environmental services they provide and their benefits to property values.

The 2015 count is the biggest tree census to happen in NYC yet. During this census, TreesCount! has partnered with TreeKit with the goal of creating a 1-to-1 relationship between the tree census data and real-life. While previously conducted censuses were numerically accurate, they were not spatially accurate. TreeKit, OpenPlans, and CartoDB are working together to create a mobile data entry tool to simplify and improve the tree mapping process. It has also stated that the 1-to-1 ration would improve the city's management of the trees. The University of Vermont has undertaken a separate project that is beneficial for TreeKit where they are creating base data of tree locations by analyzing canopy data from the Lidar satellite

Citizen Urban Science: Nodes of Future Collaboration

These early efforts to mobilize citizens to advance the collection, analysis and application of urban data in cities highlight both the promise and the nascent nature of citizen urban science today. While citizen science has spread broadly around the globe and garnered attention from national policymakers, this movement is only slowly gaining traction at the city level.[11] As these projects and others like them progress, the utility of citizen generated data is substantial. Yet further efforts are necessary to organize and direct the trajectory of citizen urban science for it to have the transformative impact demonstrated by the environmental justice movement.

In conclusion, we identify three emerging nodes of collaboration that should be targeted for further research and support in the immediate future - shared sensing infrastructure, open data, and networked social capital.

1. Shared Sensing Infrastructure

Each of these efforts began with research and development of a new instrument for data collection - the Array of Things sensor pod, the Smart Citizen Kit, and the app and tablets used by Trees Count! to record findings. This is counter intuitive, because advocates of participatory digital urbanism routinely point to mass ownership of smart phones as a fundamental enabler of citizen urban science — yet each of the projects saw the need to invest considerable resources and time in deploying a new, customized data collection platform. A key question going forward is whether increasing fragmentation of infrastructure is expected and / or desirable, or if, as Array of Things and Smart Citizen Kit implicitly aspire, there is an opportunity to co-locate most of the required sensors for a portfolio of efforts, organizations and projects on a single physical infrastructure. If this is technically feasible, who can it be made financially and institutionally feasible? (For instance, what happens when conflicts over sensor requirements, etc. occur?)

2. Open Data

The open data movement has demonstrated how sharing of information without restrictions can, as Code for America founder Jennifer Pahlka describes it — "…allow us to collaborate without talking about it".[12] However, significant obstacles inhibit realizing the full potential of open data to catalyze and accelerate citizen urban science. As we saw in environmental justice, government officials and even academic researchers are often skeptical of the quality and bias of citizen-generated data. Even where it is collected, and pressing policy issues exist, it is likely to be ignored. Citizen advocacy groups may balk at sharing data that could be used to frame a case against their preferred course of action. Researchers, while increasingly being pressured to open research data for review and subsequent use, have powerful incentives to hoard valuable research data. Future research should probe further into the value chains that develop and can be developed around urban sensor data, and the way open sharing can help accumulate and distribute that

value in equitable and productive flows. We expect that this will require deep ethnographic and managerial types of studies.

3. Networked Social Capital

The key to understanding and enabling these value chains will be focused effort on catalyzing and cultivating the networked social capital that gives rise to and sustains citizen urban science undertakings. Each of these cases addresses this node of collaboration in a substantial way — the Array of Things has created a dense network of institutional partnerships, the Smart Citizens Lab is focused on recruiting and training a grassroots cadre of citizen-scientists, and Trees Count! seeks to mobilize an army of volunteers who can be called on in times of need by government to provide a public service. Yet important questions remain: How can these models be made replicable? How do they complement or compete with each other? What models are best suited to which aspirations of citizen urban science - e.g. collection of scientific data, issue advocacy and policy change, community and economic development?

Next Steps

As these three projects demonstrate, citizen urban science has a critical role to play in bridging contemporary efforts to instrument urban environments for large-scale data collection with technology-enabled civic organizing efforts already underway around critical civic issues.

Over the next three to five years, citizen science could develop to fulfill its potential to play this role, but the movement is still undeveloped and requires considerable effort to mobilize, distill replicable lessons and models, and scale. Given the path that similar movements have evolved, we recommend exploring several activities to catalyze the next phase of development for citizen urban science globally:

- Holding an international gathering focused on building the citizen urban science movement would provide an opportunity for those active in citizen science to share and exchange their knowledge, experience, and aspirations for the movement.

- Developing an online information resource to help those interested or just starting out that want to learn more about what is happening in citizen urban science. There are currently a wealth of resources dispersed across the internet, making it difficult for smaller efforts to learn about and learn from each other. This space should contain information on successful applications of citizen science to effect change in urban communities, perhaps providing a framework or tool-kit for the efforts to be replicated.

- Researching and visualizing an ecosystem map of the key players working in citizen urban science as well as resources for those that want to know more.

Notes

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