

Community-Centered Urban Sensing: Smart Engaged Planning and Design in a Dysfunctional Urban Context

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ABSTRACT

The authors examine the problem of integrating urban sensing into engaged planning. The authors ask whether enhanced urban data and analysis can enhance resident engagement in planning and design, rather than hinder it, even when current urban planning and design practices are dysfunctional. The authors assess the outcomes of a planning and design effort in Charlottesville, Virginia, USA. Community-Centered Urban Sensing is a participatory urban sensing initiative developed by urban planners and designers, architects, landscape architects, and technologists at the University of Virginia to address the need for actionable information on the urban environment through community-engaged urban data collection and analysis. These findings address how technological urbanism moves from data to action, as well as its potential for marginalization. Finally, the authors discuss a conceptualization of smart and engaged planning that accounts for urban dysfunction. The smart cities paradigm should encompass modes and methods that function even when local urban systems are dysfunctional.

KEYWORDS

Arduino, Charlottesville, Crowdsourcing, Data, Dysfunction, Environment, Governance, Participation, Street Lighting, Technology, Virginia

INTRODUCTION

The emergence of the “smart cities” paradigm of urbanization has amplified the longstanding tension between democracy and technocracy in planning. The promise of new infrastructures, data, and analytics to address urban problems is tempered by the possibility that these systems might reduce individual and community choice, be implemented inequitably, or consume public funds better used directly in communities (Vanolo, 2014; Yates, 2017). The rise of smart cities has been paralleled by an increased interest in engaged planning that empowers communities, valuing local input and control over urban investment and design (Lydon & Garcia, 2015; Wilson, 2018). In cities with significant resources and high levels of consensus or cohesion, smart and engaged outcomes may readily emerge. However, most cities around the globe lack either the resources or the cohesion to expect that urban innovation will be readily implemented without conflict over objectives and equity. Economically distressed large cities, as well as small cities, towns, and rural areas often lack resources for technology investments, and locales of all sizes may face stresses on social cohesion and civic decisionmaking. Given this challenge, we examine the problem of integrating urban sensing, a major element of smart

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cities, into an engaged planning process. We ask how local residents can contribute to an equitable technology-driven environmental planning and design process at multiple points in that process: in the formulation of concerns, in the design of the technology, in the collection of quantitative and qualitative data, and ultimately in decisionmaking and action. In particular, we emphasize how a technology-driven process might be modified in the face of social and civic *dysfunction*.

In order to address this question, we describe and assess the outcomes of a planning and design effort in the City of Charlottesville, Virginia in the United States. Charlottesville, a small city in the Southern United States hosting a large public university, seeks to both adopt new, technologically-driven planning methods while also addressing longstanding inequities between city and university, black and white, and wealthy and low-income residents. Community-Centered Urban Sensing (CCUS) is a participatory urban sensing initiative developed by a team of urban planners and designers, architects, landscape architects, and information technologists at the University of Virginia that seeks to address the need for actionable information on the urban environment through community-engaged urban data collection and analysis. The outcomes of the CCUS program, considered in the context of Charlottesville's existing urban planning and political regime, serve as the basis for our findings.

In the paper, we begin with a review of key concepts and precedents from the literature, including smart cities and urban governance, as well as modes of participation in urban sensing. We then describe the CCUS program and present the engagement process and community response to CCUS as a case study. Our findings address challenges in how technological urbanism moves from data to action, as well as the potential for increased marginalization of some populations. Building on outcomes in Charlottesville and prior research, we discuss a conceptualization of smart and engaged planning and design that accounts for urban dysfunction and recommend modes of engagement in technological urbanism that vary from oppositional and insurgent to systematic and administrative. If new urban technologies are to become more than top-down interventions solely for well-off and well-managed cities, then the smart cities paradigm must expand to encompass modes and methods that function even when local urban systems are dysfunctional.

RESEARCH CONTEXT: SMART CITIES AND CITIZEN PARTICIPATION

Researchers, as well as public- and private-sector actors, utilize the smart cities concept to encompass the array of technological innovations being applied to urban systems, environments, and society in the early 21st century (Batty, 2013b; Caragliu, Del Bo, & Nijkamp, 2011). The literature on smart cities is expanding quickly, and applications of the term range from practical to critical. So far, the majority of the research on smart cities focuses on defining the systems and technologies that comprise urban innovation (Yigitcanlar et al., 2018). Smart cities, according to Albino (2015), are generally thought of as having key shared characteristics, including networked infrastructure, social inclusion, and environmental sustainability as objectives, typically with a business-led approach to urban development. Critical perspectives often frame smart cities projects and initiatives as part of longstanding urban trends such as the privatization of urban systems and spaces or the loss of social vibrancy and civic participation through optimization (Krivý, 2018; Vanolo, 2014; Yates, 2017). In addition, smart cities and their boosters have been characterized as hubristic, assuming that prior lessons from planning research and practice are obviated by new technology (Batty, 2014).

Smart Cities and Governance

Many smart cities projects have so far emphasized the transformation of a city's systems, rather than focusing on the role of communities and community-members in the development of new systems (AlAwadhi & Scholl, 2013). Batty et al. (2012), however, call for research that directly addresses the equity and governance challenges inherent to urban technology and development. Nilssen (2018) proposes that smart cities introduce innovations along four dimensions: technological, organizational, collaborative, and experimental, where the experimental dimension includes citizen-directed action

with cities functioning as “urban living labs” as proposed by Bulkeley et al. (2016). Even when connected to resident outcomes, smart cities projects often emphasize changing citizen behavior, rather than engaging citizens in city governance (Granier & Kudo, 2016). Yigitcanlar et al. (2018) review smart cities literature and find that community-focused smart cities research remains underdeveloped. In particular, they observe that governance issues are relatively neglected by researchers and professionals, who instead focus on smart cities technologies and systems. While communities are an “essential ingredient” of smart cities, the socio-cultural and administrative context of smart cities and its potential impacts on outcomes remain poorly understood (Yigitcanlar et al., 2018, p. 156).

Local conditions and context are a key factor in smart cities governance, including “less predictable” factors such as demographics, social pressures, community activism, and administrative cultures (Ruhlandt, 2018, p. 9). Meijer (2016) emphasizes the importance of contextual factors in smart cities implementation, including the willingness of stakeholders to take part in “collective problem-solving.” For example, residents may be resistant to engagement, resulting in the diminishment of civic and political aspects of smart cities (Cowley, Joss, & Dayot, 2018). Batty argues that the use of big data to address urban issues may shift the emphasis of urban governance from long-term planning to short-term management of urban issues (Batty, 2013a). However, the same transition from planning to management can be portrayed as insidious, where political action is edited-out of the city in favor of environmental and behavior control (Krivý, 2018). Therefore, planning must take an active role in the development of smart cities, if they are to be sustainable and equitable (Batty, 2014; Murgante & Borruso, 2015).

Crowdsourcing and Engagement

Citizen engagement in smart cities is often framed as “crowdsourcing” (Seltzer & Mahmoudi, 2013). Engagement practices frequently make use of technology, such as geographic information systems (GIS) and web-based information and communications systems (Elwood, 2002; Elwood Sarah, 2006). There are numerous approaches to crowdsourcing information about urban environments, varying in terms of technologies used, the active or passive involvement of citizens, and the purpose and use of the collected information (See et al., 2016). Certomà et al. (2015) classify urban crowdsourcing projects across two dimensions, where the first dimension defines data sources from sensors to “people engagement techniques” and the second dimension defines data availability from closed to open. They argue that participation in data collection must be fundamentally linked to participation in governance, stating that:

[Crowdsourcing] can be adapted to different contexts according to specific environmental, social, political, and economic needs, as long as they are aimed at advancing participatory governance and the related goals of recognition, participation, and redistribution. (Certomà et al., 2015, p. 103)

Grey et al. (2017) portray collaborative urbanism as the outcome of top-down and bottom-up urban practices, both informed by “big and small data,” where small data is the qualitative, contingent information that characterizes local conditions. Beyond data-driven planning research, however, planners acknowledge that not all participation is part of a sanctioned process (Lydon & Garcia, 2015). Instead, in instances where social or governmental processes are failing to meet community needs, tactical or do-it-yourself approaches that operate outside of traditional bounds may be called for (Iveson, 2013). Overall, linking spatial-data and crowdsourcing methodologies to longstanding planning challenges remains a central concern for smart city research (Roche, Nabian, Kloeckl, & Ratti, 2012).

TOOL: COMMUNITY-CENTERED URBAN SENSING

Community-Centered Urban Sensing (CCUS) is a toolkit for collecting and disseminating quantitative and qualitative spatial information about urban environments. As a multidisciplinary team (urban planners and designers, architects, landscape architects, and information technologists) based at the University of Virginia, we designed CCUS to facilitate participatory urban sensing, allowing residents and community-based organizations to contribute to urban planning and design in their neighborhoods. Participatory urban sensing can be defined as a social practice, where urban inhabitants *purposely* use sensing technologies to collect and share information about their surroundings (Lane, Eisenman, Musolesi, Miluzzo, & Campbell, 2008). As a customizable toolkit, CCUS offers multiple avenues of engagement, including quantitative data collection, qualitative photo and text inputs, and integrative analytics, all spatialized through GPS and mapping. Because each community will have varying levels of interest in and capability to potentially code, build and use sensing devices, and analyze spatial data, we have designed CCUS to allow different elements of the system to be carried out by different actors, including individual residents, community organizations, city staff, and intermediaries such as non-governmental organizations (NGOs) or universities.

The toolkit is composed of two primary components, a portable sensor array and an interactive platform for contributing information and visualizing and analyzing spatial patterns and relationships. The toolkit is built on prior precedents in urban sensing and crowdsourced, volunteered geographic information (VGI). Table 1 identifies precedents for CCUS. The precedents in Table 1 are those that specifically include functionality that directly informs CCUS and are only a small subset of the many sensing and VGI projects developed by public and private actors during the 2010s.

CCUS is motivated by a goal of facilitating urban environmental planning and design that is accessible to a diverse populace, customizable to local concerns, and incorporates spatially-precise quantitative data and analysis with qualitative contributions. Therefore, we prioritized low-cost technology, as well as functionality that allows a wide range of inputs, including sensor data, photos, and text, all of which can be presented on a customizable web interface. Figure 1 presents the components of CCUS as a system. The sensor-generated data listed in the figure are those specified for addressing the issue of nighttime street lighting in Charlottesville, Virginia, USA, the case we

Table 1. CCUS direct precedents

Project	Functionality	Components
AirCasting (2018) (http://aircasting.org/)	Measures air quality and spatial location (2.5 micron particulate matter) and posts data and mapping to open web.	• Arduino-based air quality sensor • Mobile app for recording and uploading data • Website for sharing data
Darkness Map (Hoffman, Indiana, & Madsen, 2010) (https://www.instructables.com/id/Darkness-Map-Data-Collection-Device/)	Collects light levels and spatial location to measure nighttime street lighting.	• Arduino-based light sensor
OnTheLine (El Khafif & Przybylski, 2014) (http://datalab.uwaterloo.ca/project/ontheline)	Synthesizes transit information and crowdsourced destination information to create an activity guide for transit users.	• Web-based photo contributions • Integrated transit data
Safecast (2018) (https://blog.safecast.org/)	Measure radiation level, air quality and spatial location to mitigate inefficiency of public data.	• Arduino based radiation meter, GPS, • Online mapping, • Vibrant volunteer community.

describe in greater detail in the next section. However, the sensors are customizable depending on community concerns.

The sensing device is built on the low-cost, small-footprint, low-energy Arduino computing platform. Figure 2 illustrates its components, including GPS, luminosity sensor, light color sensor, microphone, CO2 sensor, and data logger with microSD memory card. The entire device can be operated from a standard 9V battery or off-the-shelf external smartphone battery power bank. Environmental data and location are logged roughly once per 200 milliseconds, providing dense and spatially-precise information whether being carried on foot, by bike, or attached to a car. The data footprint is also small, allowing for days of data collection without the need to offload data to the CCUS webserver. The other component of CCUS is its website and backend server. The website is programed in HTML 5, JavaScript and Google Map API (application programming interface) and all of the content and analytic tools are open-source or free-to-use. CCUS is designed to operate at a neighborhood scale, though zooming in to street level and out to larger geographies is possible. Functions on the website include sensor data visualization, overlaying GIS layers including infrastructure and socio-demographic data, and an interface for uploading spatially-located photo and text comments, as well as loading photos and text into the map.

Sensor data can be collected by individuals, moving on foot, bike or car. Depending on the interests and objectives of the community, collection can be undertaken by community members, city staff, or intermediaries such as an NGO or university. We established protocols for using the device, particularly setting sensor height between 1m and 2m off the ground during collection to allow for consistent readings across individuals and transport modes. Graphical instructions for using the sensor device are included when the device is shared with individuals (see Figure 3). Residents contribute photo and text comments via the CCUS website.¹ The website is designed to be used either on mobile devices or computers, so that a smartphone camera can be directly activated from the website or previously taken photos can be selected for upload later on.

Figure 1. Community-centered urban sensing system

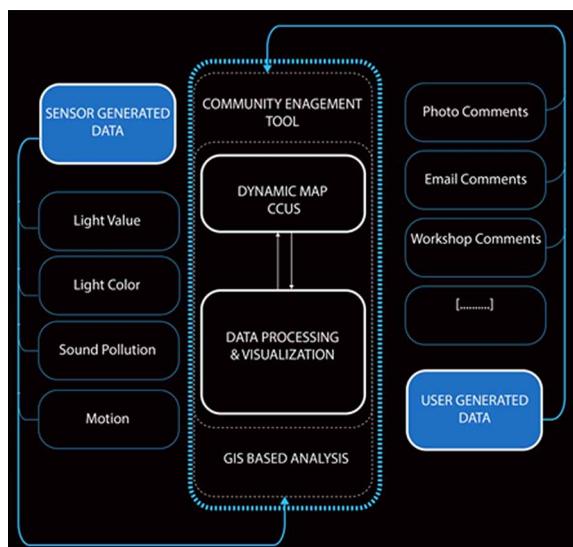
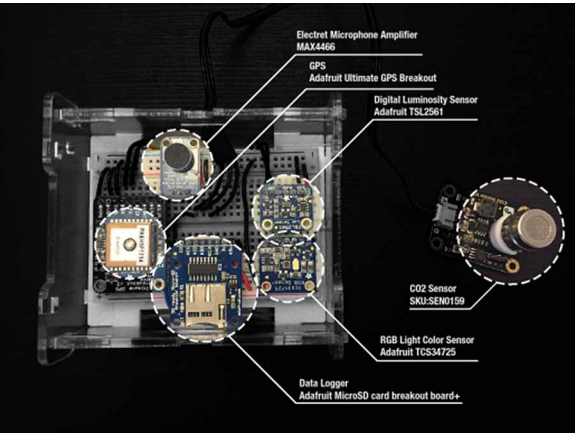


Figure 2. CCUS Arduino-based sensing device



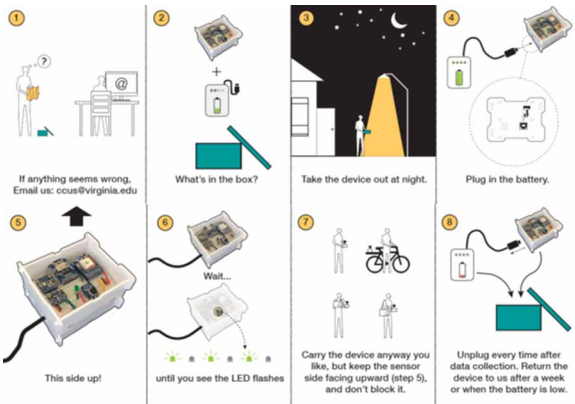
CASE STUDY: STREET LIGHTING IN CHARLOTTESVILLE, VIRGINIA, USA

We take a case study approach to describe the deployment of CCUS in Charlottesville, Virginia. Case studies in urban planning and design can be powerful tools for explaining how abstracted processes, such as participatory urban sensing, manifest in complex socio-spatio-political contexts such as cities and neighborhoods (Birch, 2012). Particularly when the results of a planning and design process are dependent on interactions between multiple causal factors, case studies can help generate new insights about why that process may or may not work as expected. We begin by presenting the socio-political context of CCUS implementation in Charlottesville and then describe the results of the yearlong project to collect data, establish mapping and analysis tools, and engage the community on the issue of nighttime street lighting.

Street Lighting and the Perpetuation of Inequality in Charlottesville

Charlottesville is a small city (population 48,000 in 2018) in the southern US state of Virginia. The city is home to the University of Virginia, a university of approximately 24,000 students in addition to a major hospital and medical school. Charlottesville's built environment reflects its history as a segregated southern American city, with separate neighborhoods for white high-income, white working

Figure 3. Participant instructions for carrying the sensor device for data collection



class, and African Americans. In general, the city did not invest significantly in public infrastructure such as streets and lighting, with narrow roads, limited sidewalks, and low quality street lighting. Particularly in traditionally African-American neighborhoods, investment in public infrastructure has been more limited and poorly maintained than in white areas. Municipal redevelopment efforts have also actively worked against African American neighborhood stability, and in the 1960s the City demolished one significant African American neighborhood, replacing it with a major road and shopping center (Saunders & Shackelford, 2005).

In more recent history, street lighting has remained limited and uneven throughout the City, and studies have demonstrated continuing deficiencies even on major streets (RK&K Consultants, 2016). Motivations for outdoor lighting regulation, design, and investment in Charlottesville continue to vary, with some advocating for darker streets to prevent light spillover into the sky and into people's homes, while others consider increased lighting as a means to safer walking and bicycling, as well as to enhanced perceptions of security. Even light color, spanning from redder to bluer light, has become an issue since the American Medical Association found that the bluer light from modern LED lighting can also disrupt sleep patterns and long term health (Stevens, Brainard, Blask, Lockley, & Motta, 2013). Charlottesville has uniquely become well known in American media over the past decade for nighttime safety deficiencies, in particular for the students of the University (Associated Press, 2017; Washington Post, 2014). At the same time, however, a perception of bias towards favoring student and higher-income, white residents' concerns, reinforced by data showing police bias against Charlottesville African-Americans by the City, has exacerbated the sense that nighttime streets are unsafe or off-limits for most residents (Suarez, 2017).

Charlottesville and its neighborhoods have made efforts to improve lighting and help address nighttime safety and livability issues. The City passed its first lighting ordinance in the 1990s, primarily regulating light spillover between properties and preserving dark skies (City of Charlottesville, n.d.). Since that time, the City has made only limited efforts to address lighting in its planning and investment. For example, its most recent Comprehensive Plan, the document which drives Charlottesville's planning and investment choices, makes only one mention of lighting, and solely in reference to park maintenance, as opposed to on-street lighting (City of Charlottesville, 2013). However, in 2016, the City hired a consultant to complete an assessment of street lighting in the City, in response to a growing sense that City streets were unsafe and insecure at night, particularly for pedestrians and bicyclists (RK&K Consultants, 2016). The assessment, however, only covered a limited number of intersections in the City center, leaving lighting issues for most of the City and its neighborhoods unaddressed. Fifeville, a traditionally African-American, working-class neighborhood of the City adjacent to the University's hospital, has been particularly concerned with lighting, and in fact a neighborhood-scaled lighting assessment was completed by a consultant (Kurasz, 2006). However, the president of the Fifeville Neighborhood Association reports that more than a decade later, none of the identified issues had been addressed.

Importantly, Charlottesville has recently been confronted by a wide range of civic and planning issues that have drowned out urban investment and design questions like street lighting, despite its importance to many of its residents. In 2017, Charlottesville was again confronted by a crisis of national and international notoriety, when white supremacists marched in the City and on the University's campus, leading to violence that injured many and killed one counter-protestor (Duggan, 2018). This crisis, brought on by Charlottesville's efforts to remove statues of Confederate generals from two of its parks, represents for many residents the City's inability to come to consensus and control its own built environment: its parks, its streets, and its neighborhoods (Spencer, 2018). Furthermore, as gentrification of traditionally African-American neighborhoods has increased, the sense that the City cannot address its own problem has become widespread. Furthermore, residents complain that recent planning efforts in Charlottesville do not truly engage residents in the planning of its future (Hays, 2018).

Working With City and Community to Introduce Community-Centered Urban Sensing

Within this context, the CCUS effort in Charlottesville provides a tool by which community members and municipal officials can address nighttime street lighting, a significant issue for local planning and design. At the outset of our engagement with this issue, we hypothesized that better quantitative data and qualitative inputs, aggregated through low-cost, readily available technologies, could provide a substantive basis for responsive urban planning and design. We envisioned CCUS as a means to bridge the technocratic need for better data on street lighting with the democratic requirement of an engaged planning process that can facilitate community input, participation, and even control during each step of a planning and design process.

In early 2017, we began by meeting with City staff to describe CCUS and discuss whether and how the toolkit might facilitate addressing lighting issues in the City. Staff members were generally supportive of deploying CCUS, and a staff engineer recognized CCUS as an instance of smart cities approaches to planning, something that the City was seeking to embrace. Staff recommended that we begin by focusing on two neighborhoods within Charlottesville, Fifeville and North Downtown. Fifeville, as described above, is a traditionally African-American community that is gentrifying and has had longstanding concerns with lighting issues (Kurasz, 2006). North Downtown is a wealthy, predominantly white neighborhood, which staff indicated had made frequent complaints about poor lighting, particularly between its residential area and the pedestrian-oriented commercial district in the center of the City. For this deployment of CCUS, we planned to collect the quantitative data ourselves, using a team of University students and collect qualitative inputs – geolocated photos and text comments – from community members.

Before collecting lighting data, we presented the CCUS concept to the neighborhood associations in both North Downtown and Fifeville. The presidents of both neighborhood associations readily invited us to present at their monthly board meetings. We first presented CCUS to the North Downtown Residents Association. We described what CCUS would do, collecting nighttime light levels, light color, noise, and carbon dioxide levels on streets in the neighborhood, mapping those data on the CCUS website, and inviting geotagged photos and comments from the public as well. We also invited residents to walk around the neighborhood and collect data using the Arduino sensing device. Overall, meeting attendees were supportive of the project and our objective of collecting fine-grained environmental data in the neighborhood. However, some attendees did raise the question of personal privacy. The privacy concern was, in general, based on a lack of familiarity with environmental sensing. We explained that the sensing device would only capture very specific data and not record audio or video, attendees were generally satisfied with our response. One concern raised by several residents stood out: Will the City act on these data and improve lighting in our neighborhood? Will they actually act on them? We relayed our prior conversations with City staff but could also not promise that the data would automatically lead to new planning or investment.

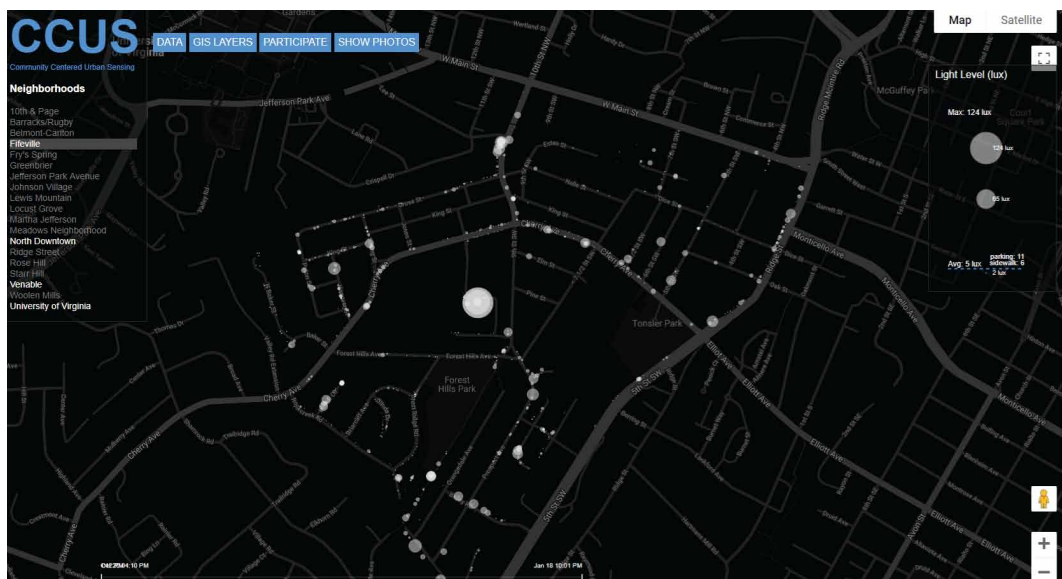
In Fifeville, we presented the same information about the project. Many in the room were supportive of the plan. The neighborhood, already in the midst of a neighborhood planning process, observed that not only were there areas that were poorly lit, but newer developments were also overlit, spilling too much light onto the street and homes. Some distinctive opposition to the project stood out. One attendee described the Arduino sensing device as a “spycam,” and was not convinced by our explanations of what the device would really do. Others expressed the concern that collecting noise data as well as light data could also be a way to further police African-American social activities that might occur on the street at night. In general, there was a more heated discussion among community members about the benefits of collecting environmental data, and the sense that the City would not act on the data anyway was raised again, as in North Downtown. Furthermore, our position as faculty and students at the University of Virginia was a significant problem for several meeting attendees. Two attendees raised the fact that University students were part of the noise and livability problem themselves, partying loudly and leaving garbage in the neighborhood. Although quantitative data

collection was being undertaken by University students, one resident was also interested in participating in the quantitative part of the process, and we facilitated her involvement by providing the device and instructions (see Figure 3). Despite the more significant concerns among Fifeville residents at the meeting, ultimately the leadership of Fifeville neighborhood association supported us proceeding with the project.

Working with the single Fifeville volunteer and students from the University, we deployed the Arduino device throughout Fifeville and North Downtown, collecting detailed data on nighttime light levels, light color, noise, and carbon dioxide. The environmental data were collected to ensure consistently valid data (following protocols for consistent horizontal lux measurement) at a minimum density of one data point per linear meter of sidewalk or street (in the absence of sidewalks) in the study areas. Figure 4 shows the results of the data collection in Fifeville, focusing on light levels. As an interactive map, the CCUS interface can display light (and other) data in multiple representations depending on the viewers' interest. Figure 4 displays a sample of all data, showing original lux readings for one out of ten points selected sequentially along streets. We also provide a "heatmap" visualization, which averages data from all readings within a given radius. The data highlight the overall low levels of lighting in Fifeville, which we compared to North Downtown as well as lighting around the University of Virginia. The data show locations where no street lighting is available at all for nighttime activities.

Following collection of the quantitative environmental data, we returned to Fifeville to present the quantitative maps and conduct a workshop with community members to train and encourage them to take geotagged photos and text comments using the CCUS participation tool. Six community members joined the workshop, a smaller group than our first presentation to the community. Those at the workshop were, as before, thoroughly convinced of the importance of street lighting as an issue and agreed that the data and comments collected by CCUS could be used to make better planning, design, and investment decisions by the City. Even after the workshop, we found participants were slow to participate in submitting photos and comments, though CCUS in Charlottesville is an open process that continues to allow input over time as residents learn more about the initiative and observe issues in their neighborhood. Overall, CCUS engaged with residents in the Charlottesville neighborhoods

Figure 4. Light levels (lux) in Fifeville neighborhood, City of Charlottesville



through three modes of participation, (1) shaping the toolkit and process, (2) collecting quantitative data, and (3) collecting qualitative data. Notably, participation was strongest in the first phase, with approximately eight North Downtown and fifteen Fifeville residents contributing feedback on how CCUS should be configured and deployed of CCUS. We did not emphasize resident participation in quantitative environmental data collection, though a single Fifeville resident volunteered to collect data. Finally, six to eight residents in each neighborhood participated in focused workshops around collecting qualitative data, and geolocated photos and comments continue to be submitted to the CCUS website. The website itself is public and continues to be used by residents and city staff, with the Fifeville data in particular currently be used to inform a street lighting element of a new local plan.

FINDINGS: MOVING FROM DATA TO ACTION, EQUITABLY

During the yearlong process of data collection and community engagement, we found that the promise of participatory urban sensing to build consensus and serve as the basis for planning and design is highly contingent on local conditions. In particular, we observe that community context had a significant impact on CCUS during its initial deployment. Despite agreement among City staff and most, if not all, community members that better data and input are needed for addressing street lighting issues in Charlottesville, the participatory aspects of CCUS, in particular, were difficult to implement.

Two key issues, repeated consistently by community members, arose during the engagement process. First, and most broadly, residents asked whether the data and input CCUS provides would actually lead to the City taking action to improve lighting in their neighborhoods. The logic of using better information to make planning and design choices was clear to everyone, but many were not confident that the City-driven processes for planning, design, and investment are capable of responding to data. The historical lack of action on lighting and the current dysfunction in the City apparent from daily news reports make the residents' general assumptions difficult to dispel. Therefore, the common response from community members is understandable: interest in and support for CCUS but a lack of willingness to invest their own time into the project.

The second issue we observed was distinct to Fifeville but raises a critique not just of the process but also the objectives of CCUS. Specifically, localized collection, analysis, and sharing of data may further the marginalization and oppression of some communities, rather than empower them. CCUS's approach was seen as threatening by some Fifeville residents, collecting detailed spatial information about a neighborhood and sharing those data openly with those inside and outside the community, including City staff and University members. The particular example of mappable noise data stands out as a possible means of identifying and repressing African American social life. However, in a changing neighborhood, where not all residents agree on what its future should look like, even lighting data can be used as a marginalizing tool, where a more powerful constituency can use the data to foster its vision of the future over the vision of a less powerful group. In Fifeville, while most residents agreed that street lighting is a major neighborhood issue, some were more concerned with a lack of security on dark streets while others saw spillover light from new developments as the key issue. The lighting data could be used to advocate for either position, depending on who controls neighborhood decisionmaking.

Broad concerns about municipal inaction or ineffectiveness and, in Fifeville, potential misuse of sensing data, require framing CCUS and smart, engaged planning within a broader context than just the application of information technologies to community-based processes. Instead, contextual issues observed in Charlottesville require that we consider urban dysfunction as a critical dimension of smart systems. In other words, in order to be smart, technological approaches to city planning and design must directly account for the level and types of dysfunction in a city's social fabric and governmental processes. Enhanced data and analytics – including urban sensing – can make a difference, but effective “smartness” in dysfunctional contexts should be more than simple process improvement. Instead, it requires knowledge of where interventions in existing processes are likely to be effective and when interventions should potentially occur outside normal, sanctioned planning processes.

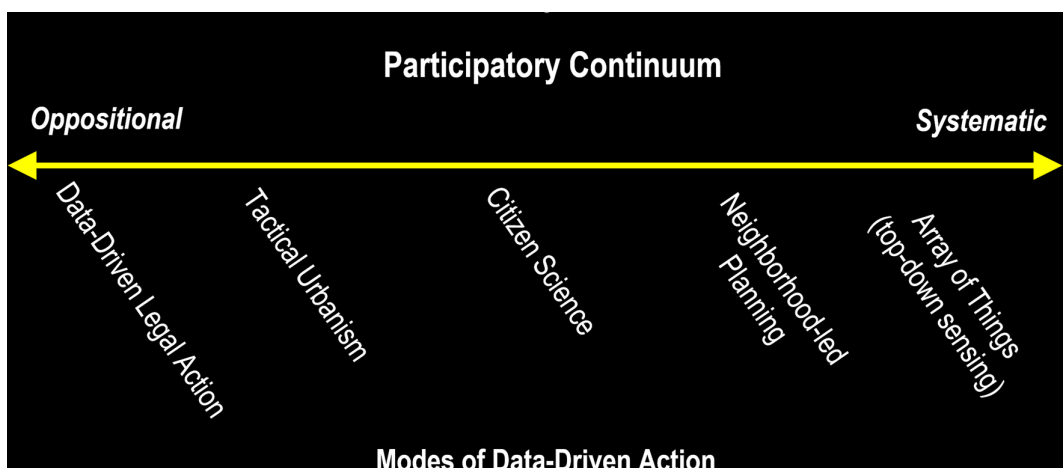
DISCUSSION: SMART CITIES UNDER THE CONDITION OF DYSFUNCTION

Building on our findings in Charlottesville, as well as previous research, we propose that smart and engaged planning and design can be conceptualized along a continuum from insurgent and oppositional to administrative and systematic. Where an initiative fits along the continuum should be determined by the level of dysfunction in existing social and governmental systems in the city. Figure 5 illustrates how this continuum can deploy data-driven technologies to address a variety of approaches to engagement. The continuum builds on the “tactical spectrum,” from unsanctioned to sanctioned, proposed by Lydon and Garcia in *Tactical Urbanism* (2015). Rather than emphasize physical interventions, we focus on how urban data and analysis can support varied approaches to resident participation, contingent on local conditions. At its most insurgent, data can be used for opposing existing social and governmental structures, such as using environmental data to pursue legal action. At its most administrative, cities can collect urban environmental data with passive approval or no awareness at all by citizens, such as in projects like Chicago’s Array of Things (Mone, 2015). Between are variations of participatory urban sensing and analytics that oppose, support, or operate outside of existing systems.

We designed the CCUS nighttime street lighting project in Charlottesville to mediate between “top-down” and “bottom-up.” In this case, “top-down” being the City of Charlottesville and its street lighting planning, design, and investment practices, and “bottom-up” being community member concerns and ideas for improving street lighting in the City. However, a more insurgent approach to CCUS may have been appropriate to local conditions. The data and analysis collected by CCUS could be used to make an argument for change in the absence of a functional planning process. Notably, more insurgent approaches must also be more specific in the changes being proposed, so that change can occur with as little friction as possible. Drawing on tactical urbanism, demonstrations and do-it-yourself interventions should be directly linked to data and analytics. In Charlottesville, CCUS has changed its approach, using the collected data and community input to design lighting installations that can be deployed without City involvement in order to demonstrate how the nighttime street environment might be enhanced.

The participatory continuum from oppositional to systematic uses of technology in urban planning parallels debates regarding bottom-up vs. top-down approaches to smart cities. Certainly, insurgent uses of urban sensing are likely to come from community-members, not governments or public-private partnerships. However, the emphasis should focus primarily on whether technology is being used

Figure 5. Participatory dimensions of smart planning interventions



as part of an existing urban process or in order to fundamentally change that process. If we seek to establish smart planning and design that effectively fosters urban change, CCUS highlights several important considerations: (a) technical complexity, (b) openness and flexibility, (c) integration with municipal systems, and (d) the role of intermediaries.

The technical complexity of an urban sensing toolkit such as CCUS may not be excessive compared to large-scale engineered systems, but it does involve coding and physical computing (HTML 5, JavaScript, web services, and Arduino programming and assembly) that few community members may have prior experience with. Unless the initiative contains an explicit “citizen science” objective, technical complexity should be minimized. However, minimizing complexity may entail tradeoffs with other considerations, such as system openness and flexibility and the role of intermediaries. Making the system open, that is non-reliant on proprietary software or hardware and making data freely available to community members, may increase technical complexity. For example, CCUS is based on open-source software, despite the fact that proprietary software, such as that provided by Environmental Systems Research Institute (ESRI) can reduce the coding burden on community members. Despite increasing technical complexity, using open-source software and data repositories also keeps the financial burden low.

Smart cities tool builders should consider whether a system is designed to function within or outside existing municipal data and analytics platforms. CCUS was built separately from the City of Charlottesville’s GIS platform, which allows flexibility in the types of data collected and the analytics provided but also means that it exists outside of the City’s sanctioned datasets. Operating outside of the City’s servers may hinder its use in sanctioned planning processes. Building a tool within a city’s existing systems may provide administrative and political validation, but may also represent co-optation of the process to community members opposed to city actions. Finally, the role of intermediaries in a smart planning process should also be carefully considered. As a part of the University of Virginia, we are community members but also frequently seen as powerful actors or even outsiders on issues of neighborhood livability. On the one hand, those building smart and engaged tools and systems must have legitimacy in the eyes of community members. When technological tools can only be developed by outside experts, whether academics, consultants, or non-governmental advocates, community members need to have some level of trust in system developers. On the other hand, outside experts must account for the social dimension of technological innovations, fully considering ethical implications of smart tools and technologies. This requires smart cities tool builders to form teams of diverse expertise in multiple dimensions, some technical and some social. Still, despite significant community outreach and transparency in our actions, some community members remain resistant to a University role in local planning and design, even if our objectives are shared.

CONCLUSION

We find that smartness is contingent on the socio-political context of the city where planning and design processes are being implemented. Participatory urban sensing, and smart cities planning generally, has been framed primarily in terms its ability to enhance existing planning processes. However, in many situations, engaged technological practices may be more effective when deployed in opposition to current practices. The experience of deploying Community-Centered Urban Sensing in Charlottesville to address nighttime street lighting issues demonstrates that urban technologies integrated into existing planning systems may not be able to overcome dysfunction inherent to those systems. However, they may be able to change those processes from the outside, if the participatory elements of the system are flexible and take into account considerations such as system complexity, openness, integration with municipal systems, and the role of intermediaries.

Future research should examine whether more tactical, insurgent approaches to data-driven planning can result in short- or long-term changes in the built environment or local planning processes. In Charlottesville, we are recentering our approach to CCUS. We will examine whether data and

analytics coupled with on-the-street lighting interventions, can accelerate planning and investment in the City. Charlottesville is a single, distinctive case, but we expect that similar situations in cities globally can be assessed for similar patterns. Future research should also investigate more flexible approaches to urban planning and design that allow for more continuous changeability in the built environment. The flexible places, such as streets with variable, programmable street lighting, are made possible by new technologies but require new approaches to community engagement so that environmental changes are directed from within the community, rather than by external actors.

While Charlottesville may be a unique case, many cities around the world face dysfunctional planning regimes due to administrative deficiencies, social conflict, or a lack of resources. In all of these cases, enhanced data and analysis capabilities provided by smart technologies may not lead to constructive action. If these hurdles cannot be overcome, we risk building ever increasing inequality within and among cities, between places with the cohesion and resources to act upon smart technologies and those places that cannot. Insofar as administrative and social dysfunction are exacerbated by limited funding for cities, tactical approaches to smart cities may be a second-best solution relative to better and more equitable funding for urbanization whether in the developed or developing world.

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ENDNOTE

¹ <http://faculty.virginia.edu/urbansensing/ccus/>

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