Chapter 8

Sensors and Civics: Toward a Community-centered Smart City

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Abstract

The ability to gather, store, and make meaning from large amounts of sensor data is becoming a technological and financial reality for cities. Many of these initiatives are happening through deals brokered between vendors, developers, and cities. They are made manifest in the environment as infrastructure – invisible to citizens and communities. We assert that in order to have community-centered smart cities, we need to transform sensor data collection and usage from invisible infrastructure into visible and legible interface. In this chapter, we compare two different urban sensing initiatives and examine the methods used for feedback between sensors and people. We question how value gets produced and communicated to citizens in urban sensing projects and what kind of oversight and ethical considerations are necessary. Finally, we make a case for "seamful" interfaces between communities, sensors, and cities that reveal their inner workings for the purposes of civic pedagogy and dialogue.

Keywords: Smart cities; sensors; civic tech; urban development; civic engagement; interface

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Becoming Data

While research and development for "smart cities" have been underway for some time, it is only recently that the ability to gather, store, and make meaning from large amounts of *sensor data* has become a technological and financial reality for cities. Urban sensor data can be defined as information that is collected through a physical device located in or trained toward the city. This includes data from fixed sensors monitoring their immediate physical surroundings for

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features such as air quality, decibel levels, and public space usage. It also comprises data produced by remote sensing platforms such as satellites, mobile sensors mounted on vehicles, and information collected through phones carried by individuals in their pockets.[1] Indeed, mobile phones are packed with sensors that can be leveraged in an urban context, including Wi-Fi, microphones, cameras, GPS chips, accelerometers, gyroscopes, proximity sensors, and ambient light sensors. Newer versions will likely include heart rate monitors, temperature sensors, and fingerprint scanners. When data are collected and contributed into the civic realm by individuals, it has been referred to as "participatory sensing" (Christin, Reinhardt, Kanhere, & Hollick, 2011) or "citizen sensing" (Gabrys, 2014) or "popular sensing" (D'Ignazio & Zuckerman, 2017).

Numerous projects that use urban sensors to monitor things such as street usage, air quality, and recycling rates are underway in cities from Bangalore to Barcelona. A central tenet of the contemporary smart city is the instrumentation of the city through networked urban sensors. Indeed, there is growing enthusiasm around urban sensors, among technology vendors and municipal governments. Markets are emerging around newly defined infrastructure needs, propelling the smart city from a distant curiosity to a mainstream imperative. Smart city discourse has captured the popular imagination as a meeting point between anxiety and promise, no longer focused on the distant future, but on the proximate present. Sensor technology is available and proliferating.

Urban sensors generate data from the environment, including from individual occupants, and as such represent a conflation between private and public space, where aggregated personal data take on the character of public infrastructure. Martin Heidegger's conception of modern technology provides some insight into this effect. When we do things with or in the midst of technology, he argues, the objects and activities of experience are converted into what he calls "standing reserve," a process through which, "everywhere everything is ordered to stand by to be immediately on hand, indeed to stand there just so that it may be on call for a further ordering" (Krell, 1993, p. 320). A sensor mounted to a street lamp collects data on the number of people walking across an intersection. That data may be used in real-time but it is simultaneously placed in a "standing reserve" for its use later. In fact, a primary quality of the paradigm shift to big data is to collect everything you can now and figure out what to do with it later. As the former director of the United States National Security Administration (NSA), Keith Alexander said in 2013: "You need the haystack to find the needle" (Gellman & Soltani, 2013).

The logic of the smart city is the transformation of the standing reserve into public infrastructure. And the logic of infrastructure is that it remains unseen. As a result, the bias in smart city growth has been invisibility – the capturing of

[1]Importantly, such mobile sensing devices can collect data on the physical and social environment that is linked to location with precise, time-stamped latitude–longitude coordinates. This allows for an increasingly high-resolution measurement of change or difference across time and space.

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data into standing reserve, and the reassertion of that data as seamless and efficient functionality. When immediacy is transformed into reserve, the power of ordering is not equally distributed. People of color, or poor people, become data, like everyone else, but with decidedly less access to ordering and with significantly more susceptibility to be ordered by others. The use of arrests data in impoverished neighborhoods to justify an increase in police presence, for example, can serve to perpetuate racism and subjugate residents (Goel, Rao, & Shroff, 2016). Or, as was the case in mid-century urban renewal efforts, that same data justified the wholesale clearance of slums (Caro, 1974). The inequities built into the seemingly neutral invisible data infrastructures have the potential to destroy marginalized communities by placing them on call to be ordered by others (Eubanks, 2018).

The challenge for the smart city, as it asserts its technocratic vision for urban function, is to make visible the interaction between human subjects, their data, and the resulting urban infrastructure. In this chapter, we ask how critical interfaces can be produced and maintained that would enable a greater diversity of choices around ordering for those with historically less power to make choices? We want to shift the discourse of smart cities *from infrastructure (invisibility) to interface (visibility)*, where the process of ordering is laid bare for the purpose of acknowledging difference and disparities. We challenge the dominant paradigm of the Internet of Things that adopts Mark Weiser's conception that "the most profound technologies are those that disappear" (Weiser, 1999, p. 3). Smart city technology is largely driven by this drive toward invisibility. Yet, as we've been discussing, the costs of such seamlessness are potentially great. As such, there is room for public sector innovation in cultivating "seamful" interfaces for the smart city, or legible interactions that contain the characteristics of accommodation and appropriation (Chalmers & Galani, 2004).

A seamful smart city interface is not simply visualization. It requires public interaction at every stage, not simply a public hearing at the start. In the smart city, before public participation, there needs to be a process of making visible. This is not a simple dichotomy of clear interfaces versus complicated interfaces, but rather the idea, following Galloway (2012), that interfaces are political and historical. Clarity and usability as design values often work to support seamlessness whereas bugs, breakdowns, and errors can bring forward the seams – "the boundaries between zones of operation and non-operation, regions of stability and difference" (Dourish & Bell, 2011, p. 120).

We begin the critical process by thinking about smart city interfaces across three overlapping dimensions: pre-deployment, in situ, and post-deployment.

(1) Pre-deployment: Who decides what to measure? What role do citizens and communities play in determining what to sense in the city, based on what (whose) value proposition and criteria?
(2) In situ: Once deployed, are urban sensors designed for legibility and participation or backstage monitoring and control? This is to say – are they conceived as interface, and thus opportunity for engagement and dialogue, or

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infrastructure, and thus designed for invisible service provision? What values do we see embodied by these design choices?

(3) Post-deployment: Given that data are collected at one time and location in the urban environment and then used to inform processes and decisions afterward, when and where are the interfaces between city, sensors, data and citizens?

These questions correspond to opportunities for the people managing urban sensors to interface with citizens and communities. In the next section, we survey the literature, secondary sources, and reports from two examples of smart city initiatives, New York's Hudson Yards and Bristol's Dampbusters, and attempt to understand how critical interfaces are produced (or not) in each dimension. These examples are by no means exhaustive, but they can help illustrate the practical difficulties of realizing seamful interfaces for the smart city.

A Quantified Community?

Hudson Yards is a 28-acre private development between 30th and 34th Street on the far west side of Manhattan. It is the largest private real-estate development in US history – expected to cost US$20 billion and involve the construction of 16 skyscrapers by its completion in 2024. The master plan includes a mix of commercial office space, retail space, residential space, a cultural space, a school, an on-site power plant, and multiple public spaces and expects to support 65,000 visitors a day. Sidewalk Labs, a company owned by Google's parent company, Alphabet, will be one of the first tenants. One of the most interesting constraints about the site is that it will continue to operate as a railyard. New York's Metropolitan Transit Authority invested US$400 million to cover existing tracks and tunnels. Thus, only 38% of the site is available for construction, making high-density planning a necessity for return on investment (Mattern, 2016).

Hudson Yards has been conceived from the beginning as a "smart district" or "quantified community." The latter is the terminology of Constantine Kontokosta, whose lab at the NYU Center for Urban Science and Progress (CUSP) is the academic partner on the project. Numerous aspects of the urban environment will be monitored by sensors, including air quality, heat islands, noise levels, and usage of public spaces. The green spaces make use of "smart soil" to help promote optimal growth even though roots cannot reach deep into the ground, since there are trains under the ground. At the building level, sensors will monitor energy and water consumption, the flow of people in and out, indoor air quality, and solid waste management (which, incidentally, will happen through chutes and vacuum tubes rather than garbage collection by the city). And finally, residents, workers, and visitors to the site will be encouraged to download the Hudson Yards app and voluntarily provide information on their health, nutrition, and mobility to the development. In return for opting-in, these citizens theoretically receive optimized services.

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The first building in Hudson Yards opened to the public in 2016, but the majority of the development is still underway in an area of the city without existing residents. As such, we talk about the development as both real and speculative, and treat it as both discourse to be analyzed and phenomena to be observed. We begin with the theoretical assumptions guiding the development. According to Kontokosta (2016, p. 16), quantified communities (QCs) are centered on stakeholder engagement: "The QC team have partnered with local stakeholders to identify priorities and goals and deploy an informatics infrastructure to develop a more complete inventory of needs and a more robust capability to evaluate alternative responses." Interestingly, because Hudson Yards stakeholders do not include residents (since there are not yet any to be consulted), this participation is sourced from the financiers and developers with financial interests in the site, rather than small businesses and residents that abut the development, potential future residents and workers, homeless people, or maintenance staff. Thus, there have been few or no opportunities for citizen engagement prior to the design and deployment of urban sensors. Mattern (2016, p. 6) asks:

> Are there opportunities for meaningful citizen participation in creating the smart technologies that will define Hudson Yards? And what about the visitors? What about the conscientious objectors? What about the residents who lack the tools for participation —"smart" devices or technological "smarts" — and who are thus subjected to the city's monitoring without being able to monitor back?

She asked these questions to CUSP and the developer and was told that the QC concept was still "under development." So, if QCs are centered on stakeholder engagement, which is doing the work of convincing powerful stakeholders (those who control the means of production) that this is the case? Historically, public participation has been a nuisance to overcome, a bug not a feature. If indeed, it is at the center of these new developments, it needs to be factored in from the very beginning. Who decides what to measure prior to deploying sensors in public space? In this case, it is driven by the private funder, authorized by the city, designed in the university, and implemented by the private firms to ultimately serve the firm's clients (who are not necessarily the same as the city's citizens).

Likewise, in its promotional materials Hudson Yards has made very specific design decisions about what the sensors and smart systems look like on site. For example, trash is sucked away in pneumatic tubes installed out of view from every building to a dispensary on 12th Ave (Clarke, 2014). No rendering of the public park or buildings includes a sensor device. Mattern (2016) points out that there is a missed opportunity for civic pedagogy and that hiding trash in chutes promotes an "out of sight, out of mind public consciousness." Developers cite aesthetic reasons for this. Vice president Michael Samuelian was quoted as

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saying: "Even in the most posh buildings uptown, you'll see trash bags in front of the building on trash day. You won't see that at Hudson Yards" (Clarke, 2014). These also translate into financial reasons. The homepage of Hudson Yards' site promotes the "iconic brands" that have decided to move in and the "wealthy buyers" who like "culture with their condo."[2] Monitoring traffic and pedestrian flows, air quality and noise, trash, and soil are not highlighted as a public activity or offered to the residents and visitors (either as education, PR or debate), but rather designed to be layered invisibly into the infrastructure like a sewage system. The creation of invisible infrastructure, concealed in trash chutes and buried underground, is consistent with Modernist dreams of efficiency, bypassing any seamful interface of the city's function. And yet, importantly, designers of smart city projects continue to present their work as "citizen centered."

As Dietmar Offenhuber and Carlo Ratti (2017) describe, when infrastructure is conceived as data, it is vastly more controllable. When infrastructure becomes legible to machines and specialized humans, it serves a purpose well beyond its immediate utility. So different questions need to be asked. Who accesses the data and in which context? In Heideggerian terms, who does the ordering and who is ordered? Promotional materials state that "operations managers will be able to monitor and react to traffic patterns, air quality, power demands, temperature, and pedestrian flow to create the most efficiently navigated and environmentally attuned neighbourhood in New York."[3] The goal for operations managers is to more efficiently tune resources to save money, to be more resilient in a crisis situation, and to provide more "personalized" experiences to residents and visitors. And Kontokosta states that instrumenting neighborhoods in this way will open up tremendous possibilities for academic research, "allowing unprecedented studies in urban planning and design, urban systems engineering and management, and the social sciences" (2016, p. 3).

So, operation managers and academic researchers have exclusive access to the data for specific purposes. But when and how do citizens, comprised of more than just Hudson Yards' paying clients, access and engage with the data? "In this universe, citizens relate to their city by consuming and administering its systems, and by serving as sources of measurable behavioral data" (Mattern, 2016, p. 4). The main mechanism for citizen engagement with sensor data would seem to be an opt-in mobile app where people volunteer their health and wellness information in return for services. And Kontokosta and other researchers are exploring ways to convince people to volunteer more of their personal information (Kontokosta, 2015). Apart from the mobile app, it is unclear whether residents and visitors would have access to any dashboards or displays about the information being monitored and collected. Certainly, these are not part of the sales strategy, which is premised on the idea that the city is "smart" but the

[2]http://www.hudsonyardsnewyork.com/
[3]http://www.hudsonyardsnewyork.com/content/uploads/2016/08/HY_Press_HYPIS_FINAL_4-15-2014_1846.pdf

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citizen needs not engage with question, debate, or worry about that smartness because the professional managers and scientists have it under control. While Kontokosta claims that focusing at the neighborhood scale "allows for meaningful interaction with, and participation by, the people who live, work, and play in that space" (2016, p. 3), Hudson Yards, as currently conceived and despite its rhetoric about being neighborhood-centered, is driven from the top-down values of efficiency, optimization, consumerism, and professional management.

A Community-centered Smart City?

In Bristol, UK, the "Dampbusters" project represents a completely different approach. It emerged as a partnership between the City Council of Bristol (UK), Ideas for Change, the Knowle West Media Centre (KWMC), and academic researchers, with the express purpose of implementing a "people-led" smart city initiative. It is notable that the project was not initiated by the community, but rather responded to consultation from these four organizations and then proceeded to consult community organizations. After these initial meetings with community groups in Bristol, the team determined that measuring dampness was the most useful active, applicable, and realistic issue to use for their pilot. From seeing the dampness-measuring initiative through to implementation in the homes of many residents in the city, the team identified various challenges and opportunities for citizen-focused urban sensing (Hassan & Balestrini, 2015). In this model, citizens were co-designers and partners in a targeted effort to pilot a single sensing effort from ideation to implementation.

Dampbusters utilizes a clear capacity building process to identify, clarify, and drive outcome-based change around the clear and present issue of dampness and its ills, including impacts upon human health. What they have dubbed "the Bristol Approach" is a self-aware model for building an interface for social infrastructure that serves as a critique of (1) smart cities projects, which are often inaccessible to key stakeholders, and (2) current public processes, which often lack effective bottom-up development and inclusivity in their approach to project development and outcomes (Hassan & Balestrini, 2015). The Bristol Approach aims to balance bottom-up and top-down planning, utilizing engagement strategies such as public art and person-to-person contact as a cultural intermediary and point of public access, and giving a diverse citizen user group a leadership role in the identification of issues and smart city solution finding.

The "city commons" is the Bristol Approach framework utilized to guide Dampbusters and other, future citizen-led urban sensing projects. The concept of the commons is meant to capture the spirit of the participatory process. They claim that it "encompasses the resources we create, the way we share the resources, and the collective agreement about how we will use the resources for the common good" (Hassan & Balestrini, 2015, p. 8). Importantly, it is meant to set up a seamful interface for a diverse user group to shape, develop, and utilize an urban sensing tool for the specific needs of local communities. The commons serves to clarify project development and governance, the generation, ownership,

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and the use of shared assets, and the deployment of skills in relation to product development and data collection in the urban environment.

The City Commons can be described as something like Wikipedia for urban data collection, in which information is generated, maintained, and utilized by all (Hassan & Balestrini, 2015). In the Dampbusters project, residents directly affected by the dampness issue served as stewards of quantitative and qualitative data collection by deploying sensors in their homes and sharing their experiences of the impact dampness has had in their day-to-day lives. During and after data collection, the Dampbusters project relied upon the Commons to systematically collect, maintain, and utilize the data collected by the sensors.

Essential pre-deployment assessments included issue relevance and interest within the community, the applicability of sensor technologies and open data to solution-finding, and a determination of the potential impact and feasibility (Hassan & Balestrini, 2015). Mechanisms for engagement, led by KWMC and Ideas for Change, included identification and teaming with already-active community groups in affected areas to build on existing social efficacy, and working with artists embedded in these communities. Enabling the community to co-design the project and data collection tools is a notable aspect of the Dampbusters project and Bristol Approach. Citizens worked together, led by experts and others with relevant technical experience, to build humidity and temperature sensors, named Frogboxes, and to deploy them in affected housing. This playful approach to sensor building functioned as what Gordon and Walter call a "meaningful inefficiency" (2016), or an approach wherein less efficient means are chosen over more efficient means to achieve a goal. That these boxes took on the shape of frogs were intended to produce a kind of delight in users, as well as visually connect the device to the idea of humidity.

The Bristol Approach team engaged experts around issues of open data, energy, and building retrofit to identify "commons tools" including data collection infrastructure and existing municipal data sets. It is worth noting that such co-design efforts require significant coordination, skills, and expertise. While the ideas were shared by the larger network, a small group of individuals were involved in the physical design and making process. Technologists were paired with citizens that had no technical experience. Participants and designers collectively agreed on open source licensing and attribution, guided by creative commons. All engagement and framing was led by the initiating project leaders.

In situ processes included tools for data collection and sharing. The Frogbox deployment occurred over two months in 2016. The team leaders established partnerships with the local energy providers, charities, and other local organizations to support the deployment of sensors in five households. The participants, recruited through active outreach, were trained to use the sensor technology and were willing to participate in the data agreement established by the City Commons. Additionally, a "community Dampbusters" team was trained to utilize the technology and share their skills with the neighborhoods. The complex balance of social efficacy – on-boarding participants and training community support teams that buy into the City Commons agreement – and reliable technology – sensors with a clear user interface that collect and transmit data

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reliably across location and were supported by local institutions – required a balance of bottom-up participation and top-down coordination and incentivization by external team leaders (Balestrini et al., 2017).

Post-deployment processes included engagement with professionals to assess the collected and shared data and action-oriented pathways toward self-help including report generation and engagement with a community damp team. Evidence generated by the effort in the form of temperature and humidity data, as well as reports of resident impact and experience, was provided to the city council. The Dampbusters initiative created a connection with the Bristol City Council to translate findings into policy recommendations, such as the licensing of private landlords. In addition to the sensors themselves, the Dampbusters team developed an online tool to enable citizens to map dampness issues and continue to share their own experiences post-deployment.

The Dampbusters project can be described as an urban sensing initiative that balances bottom-up (citizen stakeholders) and top-down (initiating institutions and external funders, along with the Bristol City Council) processes using outside experts (KWMC and Ideas for Change) to frame and coordinate the process. This balanced approach acknowledges the organizational challenges of solely citizen-led initiatives and the need to seek new approaches to urban problems that can utilize urban sensing for accessible and relevant civic projects with outcomes that are meaningful to public stakeholders (Balestrini, Diez, Marshall, Gluhak, & Rogers, 2015).

But the leap from bottom-up participatory sensing initiatives to the creation of municipal policy and sustained long-term participation remains challenging. The issues of motivation to participate, prolonged and reliable engagement, technological robustness and data quality, and clear (or relevant) incentives for post-deployment action have been recorded in participatory smart city projects (Balestrini et al., 2015). Cases that demonstrate outcomes related to policy integration and sustained adoption of participatory sensing initiatives are needed to complement the strength of the Bristol Approach, which lies in the creation of a clear framework for coordinating civic engagement to result in a project with relevance and meaning and shared ownership within a local community.

The issue of outside coordination and funding is also relevant in the Dampbusters case. While it is unclear precisely who paid the consultants to facilitate the project and develop the Bristol Approach, there is a clear demonstration of funding and coordination by both local and non-local experts and interested parties. The Bristol Approach project received some portion of its funding from the European Union's Horizon 2020 research and innovation program in the form of a grant (Hassan & Balestrini, 2015). The Bristol City Council also provided grant funding; KWMC allocated these funds to cover intervention costs and participants administered the funds through a participatory budgeting process (Balestrini et al., 2017). The fact that expert coordination and orchestration was involved is significant in that it catalyzed and sustained both municipal and citizen support and enabled the Dampbusters case to be shared and utilized as a model beyond Bristol. While bottom-up crowdfunded efforts are effective to onboard participation, more centralized organization by

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an entity that champions and facilitates the effort is key to effective and meaningful outcomes. Embedding external expertise can both foster learning and more meaningful participation (Balestrini et al., 2015). This important finding suggests that coordinated efforts to obtain external funding and organizational assistance are advantageous; however, establishing such relationships will likely become a barrier for communities with fewer resources, connections, and access to information.

Finally, moving from DIY participatory efforts to accessible and robust civic interface is a significant challenge. The scale and nature of private sector smart city funding requires that most companies are developing and deploying smart city technology directly to municipal entities so that they can deploy quickly and at a significant scale. Such companies, called "vendors" in municipal terms, develop technology remotely far ahead of outreach and deployment. Unlike large physical building projects, in which robust approval processes often require public participation and input during all stages of project development, policy for civic engagement in smart city project development and the approval of such technology is generally unprecedented. While sensing technology is generally less visually intrusive than the obvious physical impact of a real estate development project, the invisible impact of such technologies is significant and in need of policy to guide its integration into local communities (Offenhuber & Ratti, 2017).

As such, the Dampbusters and Bristol Approach case may provide a pathway for citizens to shape, and participate within, the development and deployment of larger-scale sensing infrastructures. The framework outlined by the Bristol Approach may be a platform for both DIY participatory urban sensing projects (which build awareness, educate users, and solve real community problems) and larger infrastructural sensing deployments (which are largely shielded from community input at all stages of project development). More case studies like Dampbusters are needed to build a bank of project references for citizens and invested institutions to utilize as tools for municipal and institutional advocacy. A range of cases that demonstrate effective outcomes, as well as clear funding and organizational mechanisms, would be a great contribution to the challenge of scaling up such efforts to bridge participation in both community-developed sensing and larger infrastructural sensing projects.

Conclusion

The two examples of smart city projects presented here, Hudson Yards and the Dampbusters project, are different in almost every way – scale, style, and approach. We present them not as opposites, but as two parts of a whole. The push toward the QC is present in each. With quantification comes the uncanny ability to turn human interaction into standing reserve to be ordered by others. Even if it is discursively resisted in the Bristol Approach, all smart city interfaces are built on data. Likewise, what is represented in Bristol is a people-led participatory approach that seems to have been authentically executed in Dampbusters. That same "stakeholder engagement" rhetoric is adopted in

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Hudson Yards, but rings untrue because the stakeholders consist primarily of the developers and funders. The smart city is a powerful idea, one that is stuck in the collective consciousness as a persistent promise. But like all promises that are too good to be true, it needs to be scrutinized and acted on by the receivers of that promise.

We presented an argument for the necessity of a critical interface to the smart city and proposed a more "seamful" approach to smart city projects. What is being sold as infrastructure, as a project of maximized efficiency best left invisible, is in fact interface and needs to be premised on interaction, dialogue, and feedback. The data sourced and collected in the smart city are of a private nature, even as they are aggregated, anonymized, and sold as public infrastructure. As city-dwellers, embodied and imbued with social difference, are abstracted into data, the designers of smart cities need to build structures that make visible the process. As we have demonstrated in this chapter, there is need for a *seamful* design of the smart city, where the implications of becoming data are made legible and the affordances made usable for the purpose of serving everyone, not just customers of smart city products.

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