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The smart transition: an opportunity for a sensor-based public-health risk governance?

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ABSTRACT

This contribution analyses the promises and challenges of using bottom-up produced sensors data to manage public-health risks in the (smart) city. The article criticizes traditional ways of governing public-health risks with the aim to inspect the contribution that a sensor-based risk governance may bring to the fore. The failures of the top-down model serve to illustrate that the smart transformation of the city's living environments may stimulate a better public-health risk governance and a new city's utopia. The central question this contribution addresses is: *How could the potential of a city's network of sensors and of data infrastructures contribute to smartly realizing healthier cities, free from environmental risk?* The central aim of the article is to reflect on the opportunity to combine top-down and bottom-up sensing approaches. In view of this aim, the complementary potential of top and bottom sensing is inspected. Citizen sensing practices are discussed as manifestation of the new public sphere and a taxonomy for a sensor-based risk governance is developed. The challenges hidden behind this arguably inclusive transition are dismantled.

KEYWORDS

Public-health risk; smart city; sensors; citizen sensing

Introduction

During the next decade, data-driven processes will transform urban spaces. The question on the implications of smart cities being structured by tools and processes that construct the flows of information mediating these spaces has attracted considerable policy and scholarly interest. If the predictions by smart city proponents and enthusiasts are to be believed, 'smart' solutions would give rise to new networks of initiatives and actors. Within this narrative space, there is also a growing recognition that citizens have reasonable expectations with regard to the norms and values governing the way their urban environments are managed and the access to resources and services. These expectations can, of course, be realized through careful identification and deliberation of policies and exploration of legal, educational and technological strategies.

One area that merits closer theoretical focus is the role of data-driven processes for managing public-health risks. What distinguishes these developmental opportunities

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from those in the previous era is the alignment of policy-making with critical platform infrastructures and processes for data-driven decision-making. The premise for using technology as a governance instrument to ensure the right to a city (as incorporating the right to live in a healthy environment) merits careful scrutiny since the realization of the goal will depend on citizens being 'technologically aware' (Lefebvre 1996). How then could the potential of a city's network of sensors and of data infrastructures contribute to *smartly* realizing healthier cities, free from environmental risk?

The goal of the article is to engage with the normative tensions encountered when cities are gradually transformed into living labs (Voytenko et al. 2016; Cardullo, Kitchin, and Di Feliciantonio 2018). The central argument is that no solution can emerge from the mere creation of platform infrastructures unless these are steered and oriented by human values, rights and user-facing regulations, which are also cognizant of the existing environmental and social systems (Mauelshagen et al. 2014). The article uses the narrative of 'citizens as sensors' to explore how the right to a city can be better articulated in a way that improves the governance of the city's public-health risk, specifically that deriving from environmental factors (Boulos et al. 2011b).

The methodology draws from conceptions of a participatory social city highlighted by scholars such as Boulos et al. (2011a and 2011b), Deakin and Al Waer (2011), Caragliu, Bo, and Nijkamp (2011) and Gabrys (2014). This approach motivates a theoretical and empirical understanding of the interaction between citizen sensing (citizen sensing 'in context' and 'on books'), knowledge management and governance approaches. The insights generated are underpinned by two further contributions. First, a literature review of key theoretical notions (citizen sensing and sensor-based public-health risk governance) is emphasized. Second, observations drawn from participation in a number of thematic workshops[1] and conferences[2] provide an additional layer of empirical and practical understanding.

An overview: context setting and terminological clarifications

There is no one comprehensive definition of smart cities. Townsend, for example, defines the concept in terms of its technological infrastructure (Townsend 2013). The emphasis on information and communication technologies has been questioned (Albino, Berardi, and Dangelico 2015). An arguably better understanding of the concept views communities being connected by a range of technologies (Deakin and Al Waer 2011). Finally, Kitchin, while not disapproving of these attempts, strives for a critical understanding of the smart city concept as the alignment of technology with communities inhabiting urban spaces may also encourage a conception of cities as urban utopias (Kitchin 2015). These attempts in mapping the conceptual and normative landscape of smart cities raise a much broader point, namely the close and often easily missed relationship between power and construction of urban spaces, manifest in the array of interests shaping and influencing development and innovation.

There is one major outcome in acknowledging the questions of legitimacy in any construction of smart city discourse relevant to this discussion. This outcome is identified with the introduction of a Citizen Sensing lens, which offers the opportunity of connecting citizen-generated public-health data to specific areas of the city in specific moments of time. Such outcome is possible as the data are geo-located and registered in real time and

therefore linkable to a specific spatial and temporal dimension (Kitchin 2013). The ensuing shift in focus has the potential to shed light to issues that have not been under the spotlight of the institutional monitoring systems (De Lange and de Waal 2016; De Waal and Dignum 2017; Radichi, Henckel, and Memmel 2017). Taking the case of noise monitoring, the bottom-up approach to 'sensing' noise would entail having a multiple of lay people measuring noise in their neighbourhood. These people will likely measure noise when they feel it is more annoying and would target those areas that are more exposed to noise. Being the latter considerations not always reflected in the positioning of noise measurement stations, this bottom-up flow of data could arguably provide new insights on neglected risks to which people are exposed (Allwinkle and Cruickshank 2011). The extent to which this bottom-up contribution could stimulate a better governance of public-health risk in the city has yet to be investigated, but the promises may be worth of the challenge. Before the article proceeds further, the scope and practice of citizen sensing as understood in this article needs to be clarified.

The scope and practice of citizen sensing

'Citizen sensing' can be defined as a series of practices of monitoring environmental factors using technologies operated by lay people. Following Campbell et al. (2006, 17):

> urban sensing as a departure from existing thinking on sensor networks because people are no longer just consumers of sensed data about some natural phenomenon or ecological process. Rather data about people are now sensed and collected such that the sets of producers and consumers of sensed data now overlap; people are 'in the loop' and may participate in both roles.

One way of visualizing a citizen-centred interaction in practice is the integration of smartphones and networked devices in urban platform infrastructures, which allow non-expert users to engage in new modes of environmental observation and data collection. From the perspective of deliberative democracy, citizen sensing brings with it the promise to 'expand citizen engagement in environmental issue' ('Citizen Sense' project's website).[3]

Although citizen sensing has primarily found application in the collection of geospatial data and in the environmental context (Gabrys 2016), recent trends show the growing application of citizen sensing beyond these domains, including for public health (Den Broeder et al. 2017, on the broader citizen science discussion). The rationale here is very much a reflection of a key idea in regulatory strategy, which acknowledges that 'top-down' rulemaking is less effective in attaining public policy objectives such as reducing obesity and pollution. Instead, as Black argues, creating an interpretive community requires a framework that draws on the collective intelligence of all stakeholders (Black 1997).

The discussion of the citizen sensing and public-health 'match' requires a brief outline of specificities of the first practice. Among these features, the interaction between the citizens and the Web 2.0 (Sheth 2009) that would augment these citizens into 'citizen sensors' (Sheth 2009, 87) is crucial. The sensing citizens become able to perform 'the detection of a physical presence and the conversion of that data into a signal that can be read by an observer or an instrument' (Boulos et al. 2011a, 6). The data collected in the described way is complemented with the individual's situational awareness, identified in the peculiar understanding that on-the-ground actors have on a specific context.

Citizen sensing is not just about measuring a certain risk. As Srivastava, Abdelzaher, and Szymanski (2012) underline, the sensing citizens also engage in information sharing, fusion and analysis, thus becoming data analysis points, beyond being only data collection points. As producers and analysts of data, ordinary people become producers of new knowledge (Burke et al. 2006, 2) reflecting an 'in-the-loop' understanding often missing to institutional actors intervening in the context (this is why citizen sensing has also been referred to as 'human-in-the-loop' sensing). The key element of the creation of 'participatory sensor networks' is stressed by Burke et al. (2006, 2) who suggest the importance of a net of actors adding granularity to the collection of data.

If one considers the sensing citizens as inserted in the 'smart transition' of today's cities, it is evident how the city's smartness can strengthen the sensing potential of the citizens. Furthermore, in the smart city context, the individuals may be viewed as emerging actors shaping the governance of the city. Within this active role, the contribution to the assessment and governance of the city's risks seems timely. Whereas smart city's discourses are often focused on the improvement of tech infrastructures in the urban context, the citizen sensing component suggests a user/citizen-centred and more nuanced approach to the smart transition, as including not only tech discourses but also discourses on (smart) citizenship (Gabrys 2014).

A caveat must be made: namely, the sensing citizens are not *neutral* data points. As Goodchild (2007, 218) argues, the sensing citizens are 'intelligent synthesisers and *interpreters* of local information'. The sensing citizens 'digest' the information and shape the output according to their perception of the environmental factors measured. Specifically, in the field of public-health effects of environmental factors, the subjective element plays an important role. This 'subjectivity' of the measurement may give rise to claims of partiality or bias. However, as stated in the opening lines of this article, it is not argued here that citizen sensing should substitute official measurements. Rather, it is defended that practices of citizen sensing could *complement* institutional monitoring of risks.

Elaborating on the criticisms of considering the sensing citizens *just* as sensors, it must be added that the 'citizen as sensor' approach should not be understood as a way to minimize laymen's contribution to a mechanical input. Rather, this approach has to be considered an example of how people construct technology and shape it in their uptake of sensing devices (Bijker, Hughes, and Pinch 1989). Indeed, practices of citizens operating as sensors have been recently defined as entailing 'lay people acting as intelligent interpreters through pre-existing networks, or networks created more spontaneously by events (e.g. a public-health crisis), on which they *actively observe, report, collect, analyse and disseminate* information via certain technologies' (Berti Suman 2018, 4). The creative contribution of the people, besides being 'sensors', exemplifies the socially constructed nature of the sensor technologies they use.

As extensively argued by Boulos et al. (2011a, 6), the sensing citizens bring to the table something that machine sensing lacks: namely, humans' capacity to 'contextualize, discriminate and filter'; and to accompany the sensing with 'common sense, background knowledge and experience'. In line with what argued by co-productionist thinkers (among which stands out the work of Jasanoff 2004), the 'citizen sensors' approach here discussed appears as a manifestation of how the techno-scientific order and social order mutually shape each other. The production of new public-health knowledge and the technological changes entailed in practices of citizen sensing affect the city's social

order; yet, it is equally true that the citizens with their social practices, identities, norms, conventions, discourses, instruments and institutions shape, in turn, the production of public-health knowledge and the sensing technologies. This critical and nuanced understanding of citizen sensing and of its contribution to public health will be the red line orienting the following discussion.

Defining a (sensor-based) public-health risk governance

In this section, the notion of a sensor-based public-health risk governance, as deriving from environmental factors will be illustrated, by disentangling the components of the notion, that is, sensor-based public-health risk governance; public-health risk; risk and risk governance. This work of breaking down heavily debated concepts will serve the aims of the article inasmuch as it will illustrate how these notions are political, conflictual and imbued with values. An important aspect of sensor-based public-health risk governance concerns how to engage the citizens over time. While is beyond the scope of this article to undertake a comprehensive analysis of the challenges of achieving a sustainable participation, it is pertinent to observe, as Silka notes, that any move towards creating participatory engagement processes must comprise a mix of measures – education, awareness raising, direct engagement through interviews, survey and meetings (Silka 2013).

Sensor-based risk governance

What is suggested in this paper is that the dominant ways of public-health risk governance may be improved by a reliance on a broad network of sensors, some of which operated by laymen. Indeed, this network of sensors is also identified in the citizens carrying sensing devices. The use of these devices is stimulated by a social problem, namely the issue of environmental risks endangering public health. Consequently, a sensor-based governance of the risk implies, for the aims of this article, the expansion of the monitoring points and actors from few institutionally designated measuring stations and actors, to a broader network of data collection and analysis points, represented by the sensing citizens. Therefore, the phrasing 'sensor-based' should be understood as going beyond the pure technological element, including also the human component.

Public health and risk governance

As the sensor-based risk governance is here applied to public health, it is useful to briefly define both concepts so that their importance to comprehend the pivotal role of citizen sensing can be fully illustrated.

Public health. The following definition of 'public health' provided by the World Health Organisation (WHO) facilitates the understanding the content of citizen sensing's applications. The definition describes public health as 'the art and science of preventing disease, prolonging life and *promoting health* through *the organized efforts of society*' (Acheson 1988; WHO). This phrasing is important as it also integrates into the discursive role of citizen sensing 'the *entire spectrum of health and wellbeing*, not only the eradication of particular diseases'. Particularly timely for this research is the social dimension of public health, which connects the goal of promoting health and wellbeing, with the expectation of facilitating meaningful engagements with the society at large, comprising also non-

professional members of the civil society on matters that have direct implications for their lives. This broad characterization of public health, going beyond specific diseases, underlines the democratic underpinnings of human and citizen-centred participation.

Three further points are worth emphasizing. First, it can arguably be claimed that the WHO definition is not equipped to embrace the benefits of a smart transition, which may contribute to the afore-mentioned 'organized efforts of society' to promote public health. Second, the discussion of public health requires a historical clarification. If before the Second World War, the concerns of the city's governors were more oriented to an epidemiological understanding of public health (plagues caused by poor living conditions and sanitation), the decades following the war have been afflicted by man and technology-caused diseases as lung cancer, emphysema and heart diseases linked to chemicals and air pollution. In the post-war society, technological developments (high voltage, use of lead in gasoline, the boom of the car industry, etc.) in cities caused the drastic worsening of public-health conditions of the city's dwellers. The importance of this causal relationship between technology and public-health ailments is here stressed in order to overturn this trend and present technology's potential to actually improve public health. Third, citizen sensing provides a broader frame to integrate democratic ideals and values into technology design and stimulates the cultural mindset necessary for stimulating a smart transition of the city in a way beneficial to public health.

Risk and risk governance. A number of scholars have acknowledged the challenges and opportunities of sensors in the area of public health and smart cities generally. Lupton in an important contribution to the debate on citizen sensing focuses on the surveillance and ethical dimensions (2015). Crawshaw highlighted the role of social marketing in promoting a 'behavioural turn' and the potential risks facing individual as subjects of these practices (2013). These approaches, while helpful, do not emphasize enough the public character of conceptions of risk and risk governance within the context of public health and citizen sensing. This lacuna can now be briefly addressed.

The concepts of risk and risk governance are here discussed in order to underline their complexity, due to the variety of the category of 'risk' – on one side – and to the uncertainty of certain types of risk – on the other. The complexity of today's risks demands ever improving assessment processes. Such processes should be indeed reflect the changing society and the consequently changing risks. A sensor-based, inclusive and granular risk assessment process based, also, on citizen sensing seems particularly timely within this context.

In order to define the notion of 'risk governance', it is necessary to conceptualize 'risk' and 'governance'. Risk could be broadly defined as a situation involving exposure to danger, the possibility that something unwelcome will happen, or the person or thing regarded as a threat or likely source of danger.[4] This article aligns with the definition embraced by the Dutch Health Council (1995). The Council defines 'risk' as 'the possibility, with a certain degree of probability, of damage to health, environment and goods, in combination with the nature and magnitude of the damage'. The causes of risk, according to the opinion of the Council, are action by man, natural events or combinations thereof. The Council in its definition puts particular emphasis on damage to health and damage to the environment, which is particularly relevant to the aims of this article. Risks can entail a

damage to recognized material or immaterial good, for example, public health or environmental integrity (Van Asselt and Renn 2011, 437).

'Risk' is an all-comprehensive word, as includes different typologies of risks. As the Dutch Health Council points out (1995), 'not all risks are equal'. They indeed different considerably among themselves in terms of probability and effects, dose and response, causes and factors, agent and consequences, type and magnitude, time of occurrence and duration, possibilities of recovery, etc. Arguably, only particularly complex, entangled, multi-actors risks would require the reliance on an 'outsourced' risk assessment. For simpler risks, the traditional institutional governance would suffice.

Differently, those risks that are heavily intertwined with societal dynamics specific to the context of reference cannot be managed and predicted through simplistic models. They indeed require 'a more holistic approach (that) goes beyond the usual agent-consequence analysis' (Van Asselt and Renn 2011, 436). Subtle interlinks between apparently unrelated phenomena need to be investigated, spillover effects have to be discerned and complex risk clusters must be identified. Taking again the case of noise pollution, it is often very difficult to understand the real impact of an infrastructural intervention (e.g. the construction of a new airport's runaway) on people's quiet. The case of public-health effects of the expansion of big airport hubs is explanatory of the need for inclusive approaches in assessing the risk (Berti Suman 2018). In order to perform this inclusive risk assessment, the contribution of the sensing citizens seems particularly beneficial. Furthermore, the smart city context with its data flows and infrastructures and its smart citizens may bring about a new arena to better assess risk problems. As grows the need for a more granular and inclusive management of risks, citizen sensing for (public health) risk governance is one of the possible responses that the smart transition may bring to the fore.

Moving from the abstract notion of risk to the application of this notion to public health, again the definition of the WHO seems timely. The WHO[5] defines a risk factor to public health as 'any attribute, characteristic or exposure of an individual that increases the likelihood of developing a disease or injury'. Some examples of the most important risk factors are '(…) high blood pressure, tobacco and alcohol consumption, and *unsafe water*, sanitation and hygiene …' This broad definition also includes environmental factors as risky factors for public health. In the twenty-first century, and in particular, in developed countries where sanitation and hygiene are not an issue, the main risks posed by environmental factors to public health are environmental damages and climate change (WHO).[6] An increasingly monitored city should make use of (citizens-carried) technologies to create new opportunities for assessing and even preventing environmental exposures dangerous to public health.

In order to approach the notion of 'risk governance', also the concept of governance has to be addressed. Governance has been defined as 'the multitude of actors and processes that lead to collective binding decisions' (Van Asselt and Renn 2011, 431). The relevant component of this definition is the focus on this 'multitude of actors' which is identified in governmental institutions, economic forces and civil society actors. Increasingly, the smart city has been promoted as an arena where these actors find encounters and collaboratively interact. The citizen sensing phenomena supposedly take place within this *horizontally organized* structure where both state and non-state actors interplay (Wolf 2002). Whereas in the term 'government' evoking a vertical structure there would be no room for citizen sensing, the term governance exactly embraces the complexity of

several actors shaping the scene, among which the sensing citizens have a role to play. The importance of a multitude of actors competing with the government and organized in *multi-actor networks* with different logics of action permeates the shift from 'government' to 'governance'. The present article considers citizen sensing as inserted within this fundamental shift and reflecting the new role reserved to citizen engagement in the governance-based political setting.

In bringing together risk and governance, it is worth to mention the definition of Van Asselt and Renn (2011, 431) that characterizes 'risk governance' as 'the translation of the substance and core principles of governance to the context of risk-related decision-making'. Risk governance would encompass 'both the institutional structure and the policy process that guide and restrain collective activities of a group, society or international community to regulate, reduce or control risk problems' (Renn, Klinke, and van Asselt 2011, 231). Undoubtedly, the debate on governance contributed to shape the discussion on *risk* governance. Consequently, when the latter notion arose, it already brought with itself the whole discussion informing the transition from 'government' to 'governance' and its core principles. As a matter of fact, it is not discussed the *government* of the risk, but its *governance,* thus including the above mentioned 'complex web', it is here argued that the sensing citizens can play a key role.

Lastly, it should be considered that risk is governed not only through the intervention of formal institutions and through the act of regimes, but also through *informal arrangements* (Van Asselt and Renn 2011, 432). Citizen sensing arises exactly within this informal 'zone' where non-institutional actors take the lead. The bottom-up production of knowledge, the gaining of legitimacy and the subsequent formal recognition of this informal action all occur on this arena. The sensing practices thus become part of those 'informal arrangements' arising in the city, often enhanced by the smart transition of the city itself.

Moreover, it is undoubted that allowing laymen's voice into the currently more top-down risk decision-making would increase the number of conflicting views confronting one another around the decisional table. However, as Mouffe (1999, 757) stressed, the understanding of the public sphere must include the 'multiplicity of voices that a pluralist society encompasses', as well as 'the complexity of the power structure that this network of differences implies'. This plurality of oppositional discourses and social organization would not undermine democracy. Rather, it would strengthen it. Nonetheless, in order for tech-based participatory practices, as citizen sensing, to succeed in releasing their democratic potential particular attention should be devoted to the protection of communication rights and the achievement of a just smart transition. As Cammaerts underlined (2007, 5), such rights, developed as 'a counter-hegemonic reaction against the commodification of information and communicational tools', supports a 'participatory and citizen-oriented approach to information and communication'. This approach seems indispensable to make citizen sensing more effective in promoting a more democratic governance of public-health risk in the city.

Another outcome of embedding the social and environmental dimensions into the governance discourse is that it also has the benefit of requiring a more expansive and responsive approach to governance on matters that are likely to affect individual lives. A criticism of the classic models of risk governance based on risk assessment, management and communication has been provided by Renn, Klinke, and van Asselt (2011, 231–232). In the view of the authors, these models – resulting from an evolution datable back to decades ago –

would be *outdated* and insufficient to cope with the challenges posed by the risks of today society. These models would be defeated by the complex reality that risk managers are facing nowadays, which entails the proliferation of non-institutional stakeholders willing and having the capacity to monitor and communicate risks. If one thinks to the multiple interactions of actors and factors in the (smart) city, it emerges clearly how complexity is just increasing and has to be addressed through flexible approaches. Among these flexible approaches, a sensor-based approach (to public-health risk monitoring) could stand out.

The need to rely on an 'expanded inclusion of stakeholders' (Renn, Klinke, and van Asselt 2011, 232) to improve risk governance at the city level here finds a possible solution (or at least contribution) in the 'sensorization' of the urban environment. What is suggested is that sensors operated by lay people could improve the current models of risk governance and address their failures through an inclusive and complementing strategy. It is indeed empirically proven that multi-stakeholder governance of risks has the potential to reduce the conflict surrounding a risky situation and may improve the perception of legitimacy of the final decision from these stakeholders that will have to face the consequences of this decision (Beierle and Cayford 2002). The smart transition in the city brings (among the others) the promise to be a space of mediation between different, often conflicting, interests that are somehow harmonized through the support of smart technologies. This article supports Renn, Klinke, and van Asselt's call (2011, 232) for a 'broader, more flexible and evolutionary approach' to risk governance (in the city), and does so suggesting a sensor-based risk governance.

Focusing on the specific challenges of risk governance, it should be said that, in cases of contested knowledge (like data and information on potential impacts of the environmental factor *x* on the health of the population *y*), it is difficult to define proper risk governance strategies. In these instances, the dominant trend in the classic models of risk governance is to *reduce the complexity* of the risk cause–effect chain between a hazardous agent and its impact on a risk-absorbing target (Renn, Klinke, and van Asselt 2011, 234). However, arguably this oversimplification brings about incomplete or inadequate strategies for the governance of that specific risk. Indeed, treating complex risks as simple do not reduce the complexity but just postpone the issue to a later stage, often in the strategy implementation phase. As Renn, Klinke, and van Asselt underline (2011, 236), this reduction of risk complexity often produces 'social amplification or irresponsible attenuation of the risk, sustained controversy, deadlocks, legitimacy problems, unintelligible decision-making, trade conflicts, border conflicts, expensive rebound measures, and lock-ins'.

For example, taking the case of air pollution in the city, if institutional measurements show that the operations of the factory *x* do not affect the community *y*, but the community still reports ailments, in a simplistic model there would be no room for addressing the perceived issue. Nevertheless, this perceived harm will give rise to a social conflict, if it is not acknowledged and included in the institutional risk-governance strategy. The institutions, sooner or later, will be forced to listen to this claim and eventually a new strategy for addressing the risk will have to be developed. So, why not to adopt this inclusive and broader approach from the beginning and make it part of the smart transition of the city?

Finally, it must be noted that the 'citizens as sensors' approach to the governance of public health in the (smart) city strongly challenges structures of powers, which regard the delineation between science and society as a basis for legal rationality and logic. What argued in the '60s by scholar Polanyi (1962) about an autonomous 'Republic of

Science' forbidding outside influence from society seems failing in front the complexity of today problems. It could be equally defended that such complexity would demand for a 'Scientocratic' problem solving. However, the need for public acceptance and legitimization of science-based decisions suggests that the Republic of Science cannot resist in present days. The discussion developed in this article is arguably in line with what emerged in the '80s as result of the 'Empirical Program of Relativism (EPOR)' by Collins and colleagues (1981, 1998). The programme pushed for an understanding of scientific controversies through the lens of sociology, focusing on the interpretative flexibility of experimental data and the social mechanisms of controversy closure. In the twenty-first century city, where a multitude of experimental data overlap and often conflict rather than converge, this analytical lens seems particularly precious.

By inspecting the real contribution that practices of citizen sensing can bring to the predominantly expert-based governance of public-health risk, this article connects to the STS-crafted concept of 'boundary work' (Gieryn 1995). The present article inserts in the critique to a rigorous understanding of the divide between scientific and non-scientific knowledge. The experience of citizen sensing and, more broadly, citizen science shows how these boundaries are blurred. The expert-layman divide becomes equally fuzzy and the need to overcome the 'deficit model' (Epstein 2000) based on the scientific illiteracy of non-expert people seems of growing urgency.

With these observations relating to the possible contribution of citizen sensing to public health in the data-driven city, it is now possible to identify what the shift in this discursive approach might entail for structuring the public sphere of cities and what might be the opportunities and limits of this 'new utopia'. The critique will set out in three parts: identifying a taxonomy, reflecting on a regulatory framework for a transition towards the citizen sensor approach and identifying outstanding challenges.

Discussion

The new public sphere and a taxonomy for a sensor-based risk governance

The transition from a solely expert-based governance of the risk to a 'citizen as sensor' complementary approach may be intended as a next step of what Giddens (1990) discussed as the transition between traditional (pre-modern) culture and post-traditional (modern) culture. Among the distinctive features of the modern culture identified by Giddens, particularly timely is the discussion related to knowledge. If in pre-modern societies the elderly were the 'wise possessors of knowledge' and thus defined in time and space, in a certain past and in certain locations, modern societies have to rely on expert systems. Whereas the old members of a certain communities had a sort of implicit granted legitimacy, experts in modern societies have to be trusted. This trust is often not shared among society, which leads to a high sense of uncertainty and delegitimization of experts' decisions. As extensively argued by Jasanoff (1987), the legitimacy of the final (regulatory) decision would ultimately depends upon 'the regulator's ability to reconstruct a plausible scientific rationale for the proposed action', efforts which often fail in gaining people's acceptance and trust on the final decision. Experiences like those of citizen sensing seem re-balancing this 'blind' trust-based model through the inclusion of non-experts' voice in the system, and thus provides a sort of next step to the transition analysed by Giddens.

The shift to a sensor-based governance of the traditionally state-monopolistic governance of public-health risk seems resonating with what Habermas (1991) described as the 'structural transformation of the public sphere' and consequently of the role of the state therein. A new tech-enabled public sphere where the sensing citizens become 'the public' taking responsibility for the city's public health would heavily challenge conceptions of the state as the sole regulator of public health matters. However, as Jasanoff reminds (1990), the state has already 'outsourced' part of its role in the decision-making over complex problems. The author takes the example of the hybrid (public–private) advisory boards that provide governments with scientific and technical advice, being extragovernmental institutions aimed at developing scientific insight through research and interpreting it on behalf of government regulation. In such interpretation, science would already be 'negotiated' and become 'contingent' to the specific regulation that has to be implemented. Within such scenario, hypothesizing a different form of 'out-sourcing' (or, better, inclusion in the institutional decision-making process) of risk assessment this time to the citizens, rather than to experts might sound not too futuristic. Furthermore, it is here advocated that both systems should be maintained in place, the expert-advisory system but also a contribution from the bottom actors.

Developing further Habermas' contribution to the present discussion, it seems worth to mention the work of Mahlouly (2013) in which the author analysed Habermas' public sphere from the perspective of today's virtual public spaces, and concluded by identifying similarities between the eighteenth century society described by Habermas and the current digital era. The author draws an interesting parallelism between the Habermasian understanding of identity, and the potential of the connective culture to make people 'conscious of their political power' and to 'promote a democratic culture from the perspective of online activism'. This expression of subjectivities would be aligned with the underlying trigger that make the citizens become sensing actors. Nonetheless, as Mahlouly rightly argues (2013, 18), 'it is not clear to what extent this form of political engagement is sustainable in the context of a representative democracy', from which the need to inspect avenues for harmonizing bottom-up participatory practices as citizen sensing with institutional patterns of risk governance.

A taxonomy on the contributory potential of citizen sensing to public-health risk governance could arguably stem from the theory of the complexity of society (Castells 1996), through its reinterpretation given by Elizabeth Fisher in her article titled 'Framing Risk Regulation: A Critical Reflection' (2013). Both authors elaborate on the complex adaptive system theory and on the theory of bottom-up patterns of change. These theories are particularly relevant to the aims of this article because they focus on a diverse variety of intelligent agents (here understood as laymen), interrelated through networks which, in turn, are connected to external environments in a permeable manner. Specific attention is paid to bottom-up initiated patterns of change that are able to cause instability in the overall system state. This phenomenon is exemplified by the 'butterfly metaphor': one small initiative in a system that may cause a swirling effect in the system as a whole. It is here argued that the discussed patterns of change can also include citizen sensing initiatives, through which individuals can generate a 'swirling effect' in the city's public-health policy-making.

Towards a regulatory framework for a sensor-based public-health risk governance

The underlying aim of this article is to understand how the 'citizens as sensors' approach can challenge and reshape the classic models of public health risk governance in the city by including a bottom-up contribution here identified as practices of citizen sensing. In order to achieve this goal, the article discussed relevant socio-legal scholarship represented by authors like Renn, Klinke, van Asselt, Wolf, Bulkeley, Brooks, Adger, Habermas, Haraway, Taylor, etc. The call coming from this body of knowledge urges the achievement of an adaptive and integrative approach to risk governance. Arguably, this transformation should start from *structural and procedural* changes in how risks are managed. Such structural and procedural changes may happen at the city level and, in particular, in those cities branded as 'smart', where technological progresses promise substantial improvements of the city governance.

The preceding discussion on the shortcomings of the current models of risk governance suggests that there may room for substantial change in how risks are governed in the (smart) city. Within the smart transition, a sensor-based public health risk governance should have the following characteristics:

- It should rely on the data and sensor infrastructure both of the city (publicly available) and of the citizens (privately owned devices). For example, in the above presented scenario of noise monitoring, the data should be collected both through official noise monitoring stations, but the concerned citizens should be also able to provide noise data collected through their smartphones and sensors.
- It should be designed with a view to integrating expert knowledge (gathered through institutional monitoring stations) with lay knowledge (collected through sensors in the hands of laymen). Again taking the case of a noise problem, the institutional gathered data should be confronted with citizen sensed-data in order to assess whether there are discrepancies and, if so, how to interpret and address them.
- It should be adaptive and reflexive of the specific risks faced by a certain city and its citizens. In the scenario presented on noise, the official and unofficial data should be analysed taking into account the specificities of the context in which the monitoring actors are intervening and their context-related variables, for example, the existence of a previous conflict between the citizens and the institutions, the presence of other social issues that worsen the situation, the level of trust in the state of that specific community, etc.

All the afore-mentioned points should be embedded in the city's planning and design strategies and should be the outcome of participatory processes and inclusive risk governance.

It has been suggested in the article that this transition towards a sensor-based public health risk governance may occur through practices of citizen sensing. In an integrative approach, the sensing citizens should not be considered aside from the institutions monitoring risks. Rather, the action of the first should converge with the efforts of the latter. Nonetheless, for the bottom-up input to be trusted and recognized by the institutional level, a change in the institutional mind set should occur. This 'turning point' may coincide

Figure 1. Convergence of citizen sensing in the current models of risk governance.

with the rise of unexpected and alternative risk measurement systems falling under the umbrella of citizen sensing practices that eventually succeed in complementing top-down risk governance strategies (Figure 1).

Two aspects of this proposed sensor-based public-health risk governance in the smart city should be addressed. First, it is crucial to add that citizen sensing for public-health risk governance is not *just a practice*, it also and most importantly, a *regulatory option* aimed at managing and harmonizing the often conflicting rights, interests and values of various actors within the smart city context. Whereas the institutional setting is designed to give room for expert knowledge (and interests) in risk governance, differently citizen sensing may bring to the fore the voice (and interests) of laymen. The two sets of interests can find an encounter in the smart city arena through practices of participatory monitoring of public-health risks. From this encounter, a strengthened risk governance may arise.

The second aspect that should be addressed is that of the need to define a benchmark system for deciding which rights, interests and values, among the vast array of those defended by the smart city actors, should be prioritized in a sensor-based public health risk governance. This benchmark should be contextual to a specific city and its citizens as well as its technological infrastructure. Despite the importance of taking into account context-specific variables, it is advisable to set a standard regulatory toolkit orienting this benchmarking operation. This because, ideally, citizen sensing practices should equally contribute to improving risk governance in different cities. Through a 'standard' regulatory package, an equal implementation of citizen sensing in (smart) cities placed in different contexts and cultures could be granted. A similar regulatory toolkit should provide for:

- Mechanisms to grant data validity (accuracy, reliability and trustworthiness) of the sensor-produced information;
- Mechanisms to avoid citizens' measuring and perception biases and for addressing the risk of partiality in the monitoring;
- Mechanisms to promote understanding and agreement on the nature and extent of the risk problem to which citizen sensing is applied;
- Mechanisms to stimulate mutual trust in the respective measuring systems and in the data produced, both the bottom versus the top and vice versa;
- Mechanisms to create a trusted dialogue between the bottom and the top and vice versa.

These regulatory points should guarantee that citizen sensing does not rest a practice separate from the city decision-making, but actually becomes able to contribute to the city's policies and to converge into top-down risk governance strategies.

Challenges of the proposed solution

The 'citizens as sensors' approach as an avenue to a better governance of public health risk in the (smart) city also opens avenues to serious concerns. The sensing citizens are, first, people who have access and can access technology. Second, they are people who care about public health risk and choose to contribute to its assessment. Elder people, immigrants communities, differently able fringes of society could again be excluded from the generation of knowledge to orient decisions. This introduces the question of partial perspective and power relations in scientific knowledge production. As Haraway debated in the late 1988, who participates in or is excluded from knowledge production does matter for what we know (Haraway 1988). Although more oriented to gender unbalances in knowledge production, Haraway's lesson seems useful to this discussion, to the extent that it stresses the importance of understanding who, among the diverse multitude of citizens, actually engage in the sensing and how this influences the contribution thereof.

The concerns raised by an even more partial assessing of public health risk – when only the tech, connected citizens contribute to it – links back to what Taylor (2014) claimed in her book titled 'The People's Platform'. The author extensively discussed how open systems can in the end be as inegalitarian as the pre-Internet and Open Web ones. In the supposedly no-hierarchy, no-elites rhetoric of the Internet promotion is hidden the reality that the Internet, in fact, amplifies already existing divides, at least as much as it ameliorates them. Discourses on the web as a technology of liberation and a tool to enhance democracy fail before the acknowledgment that, even there, not all actors can participate equally. A number of gatekeepers allow and deny access; structures of power just migrate to another dimension. There are certainly great opportunities but, as Taylor stresses, these opportunities will not derive from technology alone. Society has to steer the web to truly become 'a people's platform'. Similarly, the democratic potential of citizen sensing will not spring up from the sole fact that people have sensors through which they can monitor risks. The embedding of such sensing in values and rights and the support of wise regulations should accompany and shape the process.

Conclusions

The theoretical concepts discussed and the discourses analysed show that there is no straightforward answer to the questions raised in this article. However, a hypothesis has been advanced, namely that citizen sensing is a practice *and* a regulatory option likely to improve the governance of public health risks in the city, by adding local knowledge and situational awareness to institutional practices of risk governance. It has been debated that the potential of a city's network of sensors and of data infrastructures can actually contribute to smartly realizing healthier cities, free from environmental risk, through the active collaboration of the smart city's dwellers. The sought alignment of technology with communities' needs has been presented also as a way to encouraging a

conception of cities as urban utopias. Yet it has been shown that for citizen sensing to be a tool for co-governing a risk, towards a new city's utopia, a certain number of features must be respected, among which the adoption of mechanisms to ensure the validity of the data produced in a bottom-up fashion.

Furthermore, beyond providing new useful data, citizen sensing and a sensor-based public health-risk governance bring the promise to create a dialogue between conflicting rights, interests and values. Such critical and constructive confrontation may contribute to the resiliency and the progress of societal response to risks. This dialogue has been derived from the right to the city as including the need to improve the governance of the city's public health risk derived from environmental factors. For this dialogue to be established, it has been stressed the need to set a benchmark system orienting the regulators of the city in the difficult choice of which rights, interests and values to prioritize. Whereas a standard benchmark system is not definable, it has been possible to outline a series of regulatory guidelines for the city's actors to engage with such benchmarking efforts.

Lastly, it necessary to underline that the hypothesis discussed in this article should be proven in the empirical reality of citizen sensing practices. However, as stressed earlier (Berti Suman 2018), empirical evidence on the potential of citizen sensing for public health risk governance is still limited, and researchable examples of large-scale citizen sensing initiatives are scarce. This article contributed to this under-researched field by discussing citizen sensing for a sensor-based public health risk governance in the context of the smart city transition. As the 'smartization' and 'sensorization' of the city and its citizens is an ever-growing phenomenon, it is expected that this subject will be greatly researched in the near future. This article ideally added 'a brick' to this blossoming research area.

Notes

1. Lorentz Center workshop on 'Multilateral Governance of Technological Risks', 22–24 May 2017, Leiden, The Netherlands; workshop on 'Citizen Science – Gamma Radiation, Noise Annoyance and Air Quality' at the Ministerie van Infrastructuur en Milieu, 14 November 2017, Utrecht, The Netherlands; workshop on '(Un)taming Citizen Science' at KU Leuven, 4 December 2017, Leuven, Belgium.
2. Annual NILG Forum 2017 on 'Technocratic Law and Governance' at The Netherlands Institute for Law and Governance, 30 November 2017, Amsterdam, The Netherlands; Conference 'Unpacking the "Accountability Paradox" in Expert-Based Decision-making' at the Erasmus School of Law, Erasmus University of Rotterdam, 1 December 2017, Rotterdam, The Netherlands.
3. See http://citizensense.net/about/.
4. Definition by the Oxford English Dictionary, https://en.oxforddictionaries.com/definition/risk (accessed 16/09/2017).
5. WHO website, http://www.who.int/topics/risk_factors/en/ (accessed 20/09/2017).
6. WHO website, http://www.euro.who.int/en/health-topics/Health-systems/public-health-services/public-health-services (accessed 20/09/2017).

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