An urban ecology critique on the “Smart City” model

Article in Journal of Cleaner Production · June 2017
DOI: 10.1016/j.jclepro.2017.06.191

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ABSTRACT

The aim of this letter is to raise some critical concerns and gaps in the booming literature on Smart Cities; concerns that we think deserve greater attention from scientists, policy makers and urban planners. Using an urban ecology lens, we provide some reflections that need to forgo any wider-scale implementation of the Smart City-model with the goal to enhance urban sustainability. We discuss that the Smart City literature must better include analysis around social sustainability issues for city dwellers. Focus here should start on health issues and more critical analysis about whom the Smart City is for. Also, the literature must address issues of resilience and cyber security, including how Smart City solutions may affect the autonomy of urban governance, personal integrity and how it may affect the resilience of infrastructures that provide inhabitants with basic needs, such as food, energy and water security. A third major gap in this literature is how smart city developments may change human-nature relations. Focus here should start on how Smart City technologies may hinder or support children’s learning towards a stronger psychological connection with nature. Discussions are also needed on how the Smart City model may affect pro-environmental behavior more broadly.

1. Introduction

In his film, Lo and Behold: Reveries of the Connected World (2016), world-renown film maker, Werner Herzog, asks his interview subjects if the Internet dreams of itself. While nobody has a real answer to this question, Herzog believes that asking a deep question is sometimes more important than getting a straight answer. Considering that scientists believe that we soon will be able to twitter over our own thoughts, Herzog’s question is certainly intriguing. No one actually knows where the future technologies will lead us. Increasingly, though, information and communication technology (ICT) runs our daily affairs, and more recently it is claimed that the Internet of Things (IoT) will make our cities “smarter”; hence the term “smart city” has quickly become a present-day buzzword in the debate on sustainable urban development. This is also mirrored in the dramatic increase of the number of publications addressing the Smart City concept (Fig. 1).

As resilience scientists, we have increasingly being exposed to the “smart city” concept at various urban planning conferences, nationally as well as internationally. When the UN met in Quito 2016 to discuss Urban Sustainability during the Habitat III conference, one profound new policy direction was that smart cities entered the scene as a promising paradigm for a transition towards both urban resilience and urban sustainability (UN-Habitat, 2016, p. 45). The Swedish government is also investing substantial amount of research funds in the coming decades on the Smart City model (Prop, 2016, p. 113).

The aim of this letter is to raise some critical concerns and gaps in the booming literature on Smart Cities; concerns that we think deserve greater attention from scientists, policy makers and urban planners. Here we use an urban ecology lens to do so. Urban ecology emerged in the 1990s with the concepts of ecological footprints (Rees, 1992), extended versions of urban metabolism (Newman, 1999) and with research on urban ecosystem services (Bolund and Hunhammar, 1999). Our theoretical roots lie in resilience thinking where cities are complex adaptive systems inevitably characterized by uncertainty, change and surprise and where resilience in essence deals with buffering capacity and potential for transformation, in relation to internal and external disturbances (Berkes et al., 2003). This line offers an important alternative perspective, since it views humans as part of an intricate and complex web of life that goes way beyond the borders of any city, and where resilience is viewed as the capacity of (urban) social–ecological systems to absorb shocks, utilize them, reorganize and continue to develop without losing fundamental functions (Carpenter and Folke, 2006). The UN prospects urbanization to result in urban dwellers to grow from 3.2 billion 2005, to ca. 6.4 billion by 2050 (UN, 2014; UN, 2015; UN-Habitat, 2016). While there are multiple socio-economic challenges with such massive demographic transition, detrimental environmental impacts may also follow unless adequate measures are taken (UN-Habitat, 2016). In just a few decades urban ecology has spurred discussions that cities must offer stronger stewardship of ecosystems inside and outside their borders and that planning must support designs that enable citizens to cognitively reconnect with the Biosphere (Colding, 2007; Andersson et al., 2014). Urban ecology also highlights the functions of ecosystem services, such as those generated by urban agriculture or wetlands, as technologies, for building urban resilience.
towards extreme external disturbances (Barthel et al., 2015; Lewis, 2015; McPherson et al., 2015; Bren d’Amour et al., 2017).

We believe reflections on the concerns outlined below need to forgo any wider-scale implementation of the Smart City-model with the goal to enhance urban sustainability. Right now, however, the Smart City-model is taken more or less as a given good for creating sustainable cities (de Jong et al., 2015), a viewpoint with several blind spots that we shall return to later. A number of more groundbreaking questions need also deeper critical reflection and democratic discussions; who develops and who will control and use these systems, and who might be the winners and losers of such developments? Questions of this type deserve careful analysis and even deep philosophical pondering in wider society so as to minimize unwanted surprises (Luque-Ayala and Marvin, 2016; March 2016; Hollands, 2015).

Although the term “Smart City” was coined three decades ago (Van Bastelaer, 1998), our Scopus database (search) query1 gave rise to 6770 documents dealing with ‘smart city’ or ‘smart cities’. These include articles and other papers, such as proceeding papers, books, book chapters or doctoral theses. It is the fastest growing discourse within the wider umbrella of urban sustainability (de Jong et al., 2015). Despite the sheer number of documents only a handful reviews of the Smart City exist (for example Chourabi et al., 2012; Anthopoulos, 2015; Meijer and Rodriguez Bolivar, 2016; Ahvenniemi et al., 2017), with none applying an urban ecology lens for analysis. In fact, when retrieving all ecology related publications on Smart City we only retrieved 7 documents.2

As with other popular “buzzwords” there is a multitude of definitions of what smart city actually means. In many cases authors do not even bother to define the concept. In this paper we adhere to a broad definition of Smart City as “a city in which ICT is merged with traditional infrastructure, coordinated and integrated using new digital technologies” (Batty et al., 2012, p. 481). More simply put, Smart City could be described by the words: ‘digital’, ‘IoT’, and by that urban infrastructures will be ‘wired-in’. This letter draws partly on previous critique on the Smart City model, arguing that discourses around this concept are ‘deeply rooted in seductive and normative visions of the future where digital technology stands as the primary force for change’ (Luque-Ayala and Marvin, 2016, p. 2105).

2. Smart City and the sociotechnological worldview

The literature around the Smart City concept appears to have become an increasingly dominant category of urban ecological modernization, a paradigm placing particular emphasis on reconciling and mutually enhancing economy and ecology. However, this literature places almost no emphasis on ecological sustainability (de Jong et al., 2015). Having in large a sole entrepreneurially driven, socio-technological focus “Smart City” is normally seen as contributing to urban sustainability with the basic idea being that there are presumed positive feedback loops between a high-tech business and the resulting public benefits, denoting to that smart technologies and the IoT serve social and public ends (Fig. 2). The ultimate goal of Smart City technologies is to optimize control of city systems, where people are at the center of a city’s transformation and also serving as “sources of data” (Naphade et al., 2011). A major aim of this world view is to boost the effectiveness of city governance by creating positive feedback loops between human users and smart technology, creating a communication paradigm in which the objects of everyday life are equipped with microcontrollers, transceivers for digital communication, and suitable protocol stacks that will make them able to communicate with one another and with the users (Zanella et al., 2014, p. 22).

There is an obvious interest from the ICT industry and big vendors to utilize this emerging market and to develop respective products (Anthopoulos, 2015; de Jong et al., 2015). The goal of those companies is to develop low cost sensors for collecting big data and computer networks where traffic and infrastructures can move more efficiently and public resources are better allocated (http://www.forbes.com/sites/jonmarkman/2016/09/06/google-takes-big-data-to-smart-cities/#371a0f3128de).

An evident goal of the Smart City model is to reduce costs, improve efficiencies, and improve quality of life of citizens thereby providing urban planners with tools to exploit various sources of information about human behavior (Naphade et al., 2011, p. 32). For example, big data could contribute to urban planning and governance by creating what Batty et al. (2012, p. 491) refer to as “joined-up planning” that “enables system-wide effects to be tracked, understood and built into the very responses and designs that characterize the operations and functions of the city” and by developing ICTs that could “ensure equity, fairness and realize a better quality of city life”. This can hypothetically ensure informed

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1 Downloaded from the Stockholm University Library on January 12, 2017, and using the search options ‘all text’, ‘article title’, ‘abstract’ and ‘keywords’.

2 The Scopus database search query was performed on October 27, 2016. The word ‘smart city’ or ‘smart cities’ AND ‘ecosystems’ AND ‘species’ or ‘biodiversity’ were entered in all fields and searched in the options ‘all text’, ‘article title’, ‘abstract’ and ‘keywords’.

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![Diagram over the development of publications on “smart city”/“smart cities” as provided from the Scopus database. Source: modified from Scopus.](image-url)
participation and create shared knowledge for more democratic forms of city governance. No doubt, an urban IoT can provide a plethora of public services to its citizens (Zanella et al., 2014). By computerizing and monitoring routine functions of individuals, buildings, traffic systems etc. the functioning of cities could potentially be improved. However, to what extent ICTs could form a sort of “planetary nervous system” (Batty et al., 2012) remains in large to be seen; for one thing, the realization of a more complete IoT network for a city has so far not been established yet making it hard to draw any best practice conclusions.

3. Resiliency and cyber security of the Smart City

While efficiency and economic expansion often are beneficial for society, the resiliency question of the Smart City-model is often entirely avoided in the current debate. A question of immense importance is the security aspects involved in making our cities more technologically sophisticated. Already today there are vast problems related to hacking, sabotage, and terrorism that could cause collapse of large-scale critical infrastructure, like electricity, ICT, and hospitals, just to name a few examples. As the storm ‘Sandy’ demonstrated, power grids are even vulnerable to natural hazards. In addition, a handful of players including Google, Facebook, Apple and Amazon are starting to dominate the Internet. Will changes of the power-scape of the Internet impact on the level of autonomy and self-organization related to governance of the Smart City? Moreover, it is necessary to confront how ICT-driven strategies affect risks and resilience related to basic services (Luque-Ayala and Marvin, 2016; March and Ribera-Fumaz, 2016).

The Internet seems to function as a complex network (Buchanan, 2002, p. 137), where redundancy is of crucial importance for its resilience, meaning that several seemingly redundant elements seem to be able to perform the same basic tasks, so that if one gets wiped out, the others can step into its place (cf. Elmqvist et al., 2003). Resilience scientists often advocate for modularity (or compartmentalization) in cases of over-connectedness, where modularity refers to the “degree to which a system's components may be separated and recombined” (Levin et al., 2012:4). Modularity is at least up to some point associated with increasing resilience (Levin, 2000; Bodin and Crona, 2009) by preventing harmful properties from spreading through a system, providing building blocks for reorganization in the face of change (Levin et al., 2012). In ecological systems modularity prevents diseases, invasive species and forest fires from spreading. In economic systems, it limits the spread of crises from one country to another (May et al., 2008). However, modularity comes at the expense of connectivity. Striking a balance towards intermediate levels of modularity seems to promote resilience in social-ecological systems (Rodin and Crona, 2009).

However, not only structural characteristics support resilience, learning and memory are also vital principles of resilience (Bodin and Crona, 2009; Barthel and Isendahl, 2013). Unlike the Internet, the human immune system, not only holds an immense redundancy and modularity, but it can also rapidly detect attacks and respond by isolating the damage to one part of the system, it can learn and remember attackers (pathogens), rapidly reroute information and energy, redistribute tasks, and mount immediate counter-strikes (Buchanan, 2002). Compared to biological systems, the internet is quite vulnerable, and a well-coordinated attack may well disintegrate it into isolated pieces (Buchanan, 2002).

As noted by Folke et al. (2011) new markets that develop rapidly often overwhelms the capacity of institutions to respond. One example is smart city infrastructure that develops faster than security tools do, leaving ample room for cyber-attacks of different kinds and other forms of incidents such as industrial espionage, terrorists, equipment failures, worm infestations and natural disasters (Bartoli et al., 2011; Makrushin and Dashchenko, 2017). By interconnecting systems that serve totally different purposes (e.g., traffic control and energy management), creating a “system of systems”, the complexity of such collaborating systems increases exponentially. As a result, the number of vulnerabilities in a Smart City system will be significantly higher than that of each of its sub-systems (Bartoli et al., 2011). Hence, cyber security is one of the biggest challenges facing smart city development.

How does the resilience of the internet interact with resilience infrastructures of the Smart City that supply urban people with basic needs? For instance, will the digitalization of infrastructures affect a resilient food-water-energy security, defined as the situation when people have access to safe and sufficient nutrients, fresh water and energy to meet their daily needs (cf. Barthel and Isendahl, 2013; Barthel et al., 2015)? Related to these large-scale potential societal impacts there are “major privacy concerns” to be overcome in realizing Smart City, pertaining also to for example copyright and Intellectual Property Rights of different sources of

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**Fig. 2.** A greater majority of publications on Smart City falls in the realms of subject areas that either is technologically or socially based. Source: modified from Scopus.
data sets, and the confidentiality aspects of groups and individuals (Batty et al., 2012).

4. Winners and loser in the Smart City

One of the major critique against the Smart City-model centers on the question: who is benefited by it? Hollands (2008) raise the question whether the model is for big business or for urban citizens. The Smart City has in fact been highlighted as a new frontier for capital accumulation and circulation, where it is unclear about how compatible such frontier is with the interests of urban citizens (Hollands, 2013; March and Ramon-Fumaz, 2016). Considering that the smart city market is estimated at hundreds of billions of dollars by 2020, with an annual spending reaching nearly 16 billion (Zanella et al., 2014, p. 23), the model is certainly attractive for the enterprises involved in ICT solutions. At present the big ICT players are all involved in creating what they claim to be “smarter” cities, a development which is also supported by international organizations such as the European Union (Anthopoulos and Fitisilis, 2014). Investment programs so far lies more in the direction of stronger emphasis on economic feasibility and engineering systems solutions to realize ambitions for desirable and viable urban development (de Jong et al., 2015). Hence questions arise if the Smart City is a buzzword linked to the race of cities’ self-promotion in the fierce competition of capital on a global market, rather than a new line-of thought aiming to promote environmental- and social sustainability of cities (de Jong et al., 2015).

A relevant point regarding the question of whom the Smart City is for’ pertains to the fact that it could further marginalize those not skilled in digital technologies and those that refuse using such for various reasons. In 2010, it was estimated that about 15% of Swedes do not use the Internet with most non-users found among the elderly. However, non-users could be found in all age groups even among the young. A distinguishing factor for many of them is their negative attitude to try and test new technology equipment even among the young. A distinguishing factor for many of them is their negative attitude to try and test new technology equipment even among the young.

5. Smart City for biosphere stewardship

We see a real danger that Smart City policies un-intentionally serve to further disconnect citizens from nature experiences. Social-ecological memory (Barthel et al., 2010)— refers to the accumulated collective experiences and knowledge of social groups or cultures of interaction with species and ecosystems (Andersson and Barthel, 2016). The loss of social-ecological memory may not only erode capacities for management of local ecosystems, but may also induce a shift in our connection with nature. In such view human-environmental dynamics in cities are relational and situational, and hence learning, memory and foresight build on experience (Colding and Barthel, 2013; Raymond et al., 2017). Hartig and Kahn (2016) argue also that massive urbanization and citizen densification (in combination with increased proportion of daily screen time) may trigger baseline shifts in collectively shared environmental attitudes, as urbanities may be blocked from nature experiences during their daily habits (Giusti et al., 2014). Soga et al. (2016) highlight examples where kids in Japan spend much less time in nature environments than only ten years ago, and that 12% of English kids have never visited a nature environment in the previous 12-month period. Will the Smart City model interact with such drivers of psychological dis-connection? Recently there has been an explosion of research on the topic of human-nature connections (HNC) (e.g. Restall and Conrad, 2015; Ives et al., 2017). In the environmental psychological literature, a connectedness with nature may be defined as an individual’s affective and experiential connection to nature (Mayer and Frantz, 2004, p. 504), and in natural resource management sense of place refers to how strongly a person emotionally is attached to a place, or the meanings ascribed to a place (Brehm et al., 2013). Such HNC has been studied as deep seated attitudes that relate with psychological processes that motivates pro-environmental behaviors, such as responsible energy consumption, recycling or biological conservation (e.g. Zylstra et al., 2014; Kaiser et al., 2014; Restall and Conrad, 2015). A deep-seated psychological connection with nature is easiest acquired during childhood (Giusti et al., 2014; Cheng and Monroe, 2012; Chawla and Cushing, 2007) and which persist unchanged through adulthood (Kaiser et al., 2014); if true, such disconnecting drivers threatens to undermine a fundamental leverage point, which is needed for coming sustainability transformations (Asbón et al., 2017). To quote Miller (2005, p. 431), “[i]f people no longer value nature or see it as relevant to their lives, will they be willing to invest in its protection?”

Today, an increasing number of scientists argue that we live in the era of Anthropocene. This is a proposed epoch that began when human activities started to have a significant global impact on the Biosphere of the Earth (Folke et al., 2011; Waters et al., 2016). Global drivers interact, such as climate change, urban population growth and tele-connected urban consumption behaviors
Fig. 3. Moving from a sole sociotechnological focus (A.) to a biosociotechnical focus (B.) with a focus on ecology and reconnection to the Biosphere, is necessary if the Smart City model is to positively contribute to sustainable urban development, otherwise it may instead undermine such a development.
(Grimm et al., 2008; Seto et al., 2012a, 2012b), which emergent im-
patents threaten as much as 30 to 50 percent of all species on Earth
possibly heading toward extinction by the mid-century (Thomas
et al., 2004). This is posing grand challenges, revolving around
how Smart City designs may alter attitudes and consumption
behavior. We hence need to ponder how we could design smarter
cities that run with nature, and in what ways the socio-
technological worldview could help to resolve environmental chal-
lenge and evolve into a more holistic urban sustainability concept.
Perhaps such bio-socio-technical urbanism (see Fig. 3) can make
greater use of “nature-based solutions in tandem with digital tech-
nologies” that enable habits and meaning-making, from which peo-
ple can learn how to care for the environment, simultaneously as
such bio-socio-technical solutions also provide citizens with basic
needs (https://www.iucn.org/regions/europe/our-work/nature-
based-solutions).

While Smart City solutions may be used to monitor various
environmental parameters, such as air pollution, temperature, vi-
brations, noise (Zanella et al., 2014) and make humans consume
less energy and water, and even reduce greenhouse gas emissions
(Naphade et al., 2011). It yet has to be sensitized to social-
ecological relations in the complex webs of life of which we are
all part.

6. Conclusion

According to Giddens (2016) the digital revolution will likely
affect all parts of society. As discussed herein the Smart City-
model (SC-model) holds many potential benefits for cities; still it
is fraud with a great deal of questions that need to be addressed
both in research and more broadly in society such as in public de-
pates threaten as much as 30 to 50 percent of all species on Earth
have contributed to this paper in various ways.

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Barthel, S., Bendahl, C., 2013. Urban gardens, agriculture and waters: sources of
reliability and cyber security of the SC-model, focusing on ways to make the ICT-connectility less
vulnerable to unwanted shocks and surprises. Such a discussion around resiliency should also entail how basic human needs might be safeguarded, i.e. food-energy-water security.

Secondly, more research is needed to determine beneficents and
losers of the SC paradigm. Will a new underclass emerge due to
that a certain segment of the human populace becomes “digitally
marginalized”? To what extent does SC benefit ordinary citizens?
In what ways does the SC-model affect the distribution of amenities and shared values in various urban contexts? What does increased proportion of 'screen time' in people's daily habits entail when it
comes to human cognitive development, human health issues, and children's psychological connection with nature?

Thirdly and lastly, we see a real danger that the SC-model will
untie the critical role that human connections to physical places
play in shaping pro-environmental behaviors, thus further reinforcing
unwanted "non-place urban realms" that disconnect humans to
nature. Given the massive loss of global biodiversity and climate
change on Earth today, we see an urgent need to create technolo-
gies and tools that re-connect humans to the Biosphere and pro-
mate stewardship of urban ecosystems. To what extent SC
contribute to such reconnection remains to be seen.

Acknowledgements

We like to thank the Interreg. Central Baltic Project called: LIVE
BALTIC CAMPUS (project nb. CB155), and the Beijer Institute of
Ecological Economics, for funding part of this work. Thanks to
forms project called ZEUS (dnr: 2016-01193). We also like to thank
Jonas Adner for his work with all figures. Big thanks also go to col-
leagues at the Stockholm resilience Center, the urban theme,