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Letter to the editor

An urban ecology critique on the “Smart City” model

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 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 better 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 agricultures or wetlands, *as technologies*, for building urban resilience

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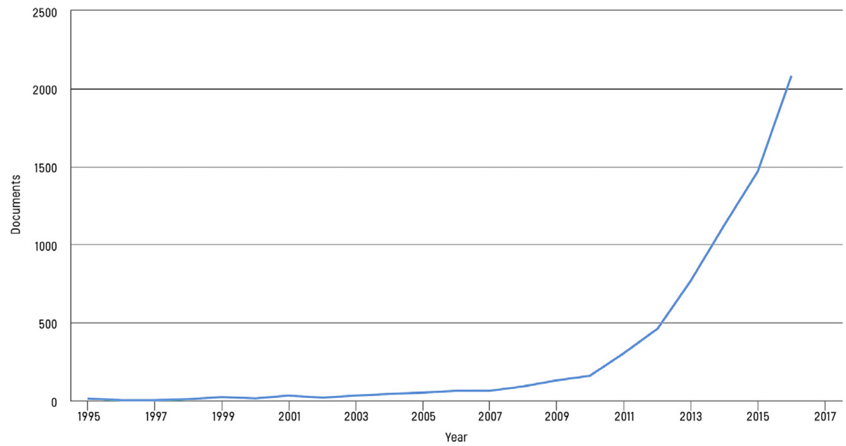

Fig. 1. Diagram over the development of publications on "smart city"/"smart cities" as provided from the Scopus database. Source: modified from Scopus.

towards extreme external disturbances (Barthel et al., 2015; Lewis, 2015; McPhearson 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) query[1] 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

[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'.

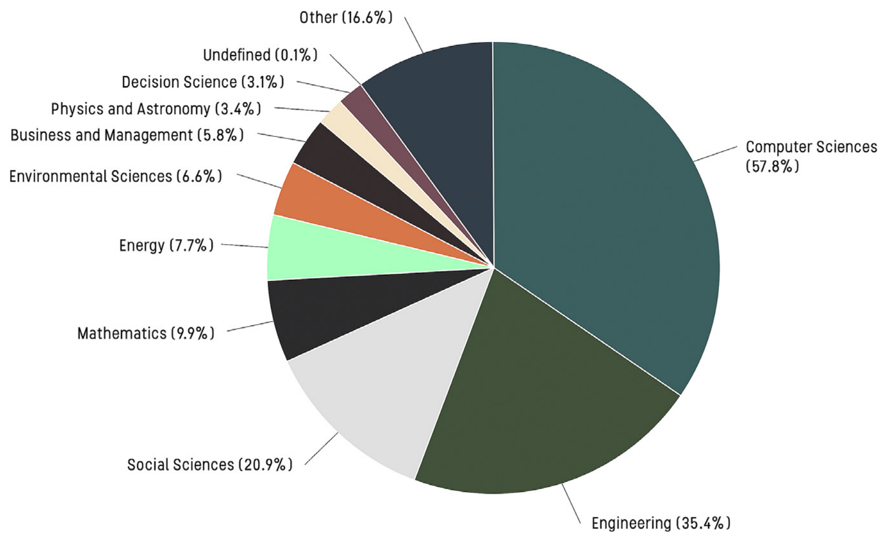

Fig. 2. A greater majority of publications on Smart City falls in the realms of subject areas that either is technologically or socially based. Source: modified from Scopus.

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 (Bodin 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 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, 2015; March and Ramon-Fumaz, 2016). Considering that the smart city market is estimated at hundreds of billion 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 Fitsilis, 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 and services (Findahl, 2013). For a lack of a better term we refer to this situation as *digital marginalization* which threatens basic issues of fairness and equal opportunity for a significant portion of the public that do not have Internet access or cannot afford technologies needed to be wired in (Luque-Ayala and Marvin, 2016). It is hence necessary to discuss how Smart City solutions may affect the distribution of amenities and shared values in various urban contexts (Hollands, 2015).

Hardly any critical thinking in the literature on Smart City has been devoted to if investments might generate ever more ‘screen time’ of people's daily routines. Increased screen time in daily routines comes often at the expense of time that before was used for interacting directly with our immediate social-ecological environments. Virtual spaces (chat rooms, Twitter, Facebook etc.) replace our need to meet and interact in traditional public space and will potentially further loosen the spatial and temporal linkages that previously bounded human activities together creating what Webber (1963) referred to as a “non-place urban realm” (i.e. Carmona et al., 2010). The notion of place emphasizes the importance of a sense of “belonging” and emotional attachment to a particular locale (Carmona et al., 2010).

The costs of the detachment from places that can afford nature experiences include less access to the health benefits to be gained from sensory interaction with nature environments (Bratman et al., 2015; Hartig and Kahn, 2016). The literature on public health related to urbanization suggest that direct experiences of nature environments offer better opportunities for moderating or coping with stress, it lowers depression, and have a significant positive impact on mental health (Thompson et al., 2012; Hartig et al., 2014; Nutsford et al., 2016). Physical activity promotes physical and mental health across the life span (Hartig et al., 2014; Cohen-Cline et al., 2015). The amount of time spent outdoors relates to how physically active an individual is, since it usually entails some form of physical activity, usually walking. Up to date there is also limited discussions in the Smart City literature on how to integrate digital technologies to enhance time spent outdoors, or how designs affect accessibility by walkability or cycling, or in other ways facilitate movement in cities. A prominent exception here is a recent publication by Marcus and Koch (2016). In summary, we see a real need for the Smart City literature to deal with issues about social sustainability in cities (Dempsey et al., 2012; Colding and Barthel, 2013; Missimer et al., 2017), including aspects of health, social justice, participation, and sense of belonging, as well as issues of cohesion; education, and safety.

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 (Abson et al., 2017). To quote Miller (2005, p. 431), “[if] 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 begun 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

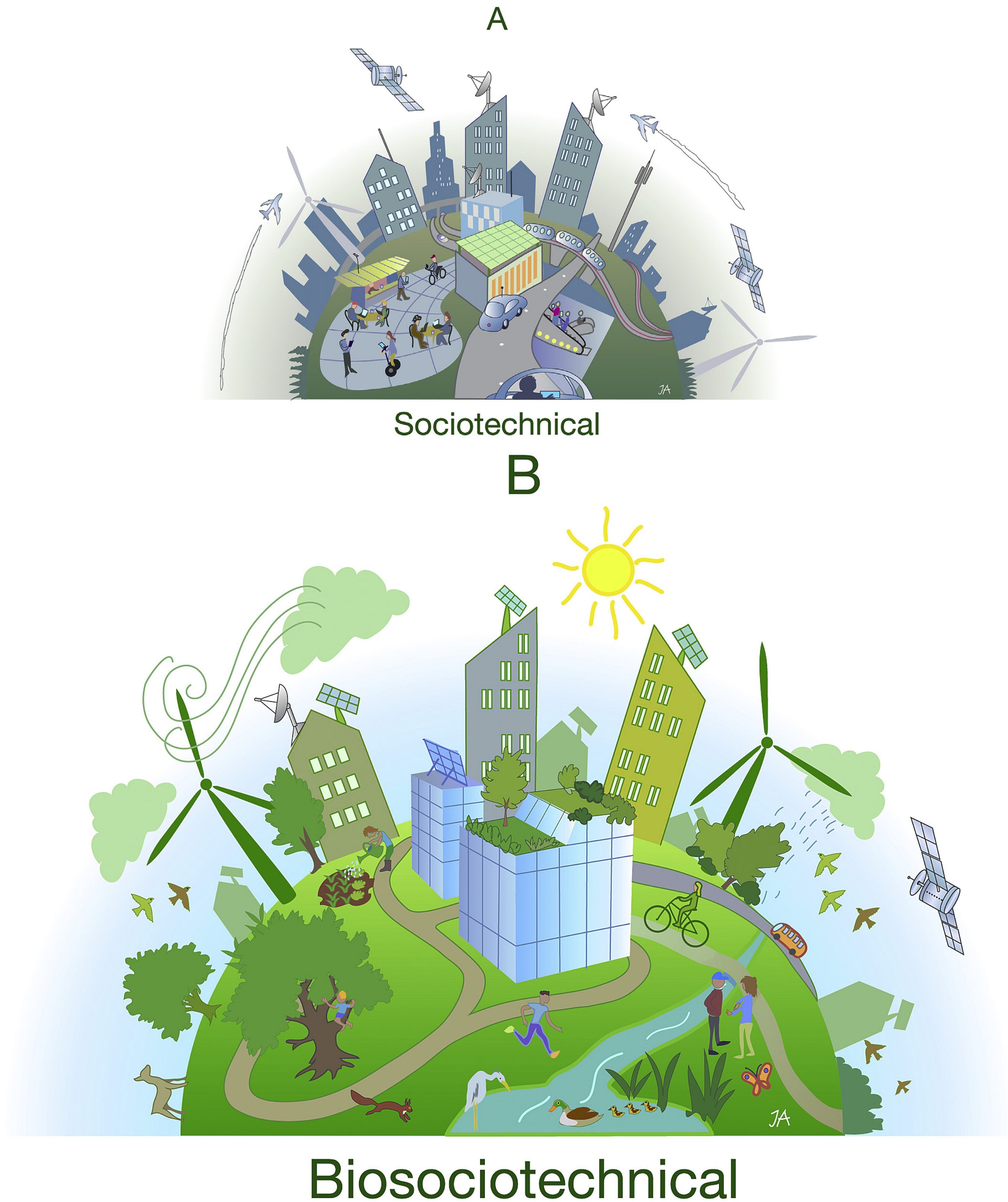

Fig. 3. Moving from a sole sociotechnological focus (A.) to a biosociotechnical focus (B.) with a focus on ecology and reconnection to the Biosphere, is necessary if the Smart City model is to positively contribute to sustainable urban development, otherwise it may instead undermine such a development.

(Grimm et al., 2008; Seto et al., 2012a, 2012b), which emergent impacts 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 challenges 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 technologies" that enable habits and meaning-making, from which people 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, vibrations, 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 debates and in media. As discussed herein, and using an urban ecology lens, these questions fall broadly into three categories. Firstly, more studies are needed on the *resiliency and cyber security* of the SC-model, focusing on ways to make the ICT-connectivity 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 *benefiters 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 technologies and tools that re-connect humans to the Biosphere and promote stewardship of urban ecosystems. To what extent SC will contribute to such reconnection remains to be seen.

Acknowledgements

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References

Abson, D.J., Fischer, J., Leventon, J., et al., 2017. Leverage points for sustainability transformation. Ambio 46 (1), 30–39.
Andersson, E., Barthel, S., 2016. Memory carriers and stewardship of metropolitan landscapes. Ecol. Indic. 70, 606–614.
Andersson, E., Barthel, S., Borgström, S., Colding, J., et al., 2014. Reconnecting cities to the Biosphere: stewardship of green infrastructure and urban ecosystem services. AMBIO 43, 445–453.
Ahvenniemi, H., Huovila, A., Pinto-Seppä, I., Airaksinen, M., 2017. What are the differences between sustainable and smart cities? Cities 60, 234–245.
Anthopoulos, L.G., 2015. Understanding the smart city domain: a literature review. Pages 9–22. In: Rodríguez-Bolívar, M.P. (Ed.), Transforming City Governments for Successful Smart Cities, Public Administration and Information Technology 8. Springer International Publishing, Switzerland.
Anthopoulos, L.G., Fitsilis, P., 2014. Smart cities and their roles in city competition: a classification. Int. J. Electron. Gov. Res. 10 (1), 63–77.
Batty, M., Axhausen, K.W., Giannotti, F., Pozdnoukhov, A., Bazzani, A., Wachowicz, M., Ouzounis, G., Portugali, Y., 2012. Smart cities of the future. Eur. Phys. J. Spec. Top. 214, 481–518.
Barthel, S., Parker, J., Ernstson, H., 2015. Food and green space in cities: a resilience lens on gardens and urban environmental movements. Urban Stud. 52 (7), 1321–1338.
Barthel, S., Isendahl, C., 2013. Urban gardens, agricultures and waters: sources of resilience for long-term food security in cities. Ecol. Econ. 86, 224–234.
Barthel, S., Folke, C., Colding, J., 2010. Social-ecological memory in urban gardens - retaining the capacity for management of ecosystem services. Glob. Environ. Change 20 (2), 255–265.
Bartoli, A., Hernández-Serrano, J., Soriano, M., Dohler, M., Kountouris, A., Barthel, D., 2011. Security and privacy in your smart city. In: Proceedings of Barcelona Smart Cities Congress 2011, 29–2 December 2011, Barcelona (Spain).
Berkes, F., Colding, J., Folke, C. (Eds.), 2003. Navigating Social-ecological Systems: Building Resilience for Complexity and Change. Cambridge Univ. Press, Cambridge, UK.
Bodin, Ö., Crona, B.I., 2009. The role of social networks in natural resource governance: what relational patterns make a difference? Glob. Environ. Change 19, 366–374.
Bolund, P., Hunhammar, S., 1999. Ecosystem services in urban areas. Ecol. Econ. 29, 293–302.
Bratman, G.N., et al., 2015. The benefits of nature experience: improved affect and cognition. Landsc. Urban Plan. 138, 41–50.
Brehm, M.J., Eisenhauer, W.B., Stedman, C.R., 2013. Environmental concern: examining the role of place meanings and place attachment. Soc. Nat. Resour. 26 (59), 522–538.
Bren d'Amour, C., Reitsma, F., Baiocchi, G., Barthel, S., et al., 2017. Future urban land expansion and implications for global croplands. PNAS 114 (1). http://dx.doi.org/10.1073/pnas.1606036114.
Buchanan, M., 2002. Small World - Uncovering Nature's Hidden Networks. Weidenfeld and Nicholson. GB. ISBN: 0753816879X.
Carmona, M., Tiesdell, S., Heath, T., Oc, T., 2010. Public Places – Urban Spaces. The Dimensions of Urban Design. Routledge, London and New York.
Carpenter, S.R., Folke, C., 2006. Ecology for transformation. Trends Ecol. Evol. 21, 309–315.
Chawla, L., Cushing, D., 2007. Education for strategic behavior. Environ. Educ. Res. 13 (4), 427–452.
Cheng, J.C.H., Monroe, M.C., 2012. Connection to nature: children's affective attitude toward nature. Environ. Behav. 44 (1), 31–49.
Chourabi, H., Nam, T., Walker, S., Gil-Garcia, J.R., Mellouli, S., Nahon, K., Pardo, T.A., Scholl, H.J., 2012. Understanding smart cities: an integrative framework. In: Pages 2289–2297 in Proceedings of the 45th Hawaii International Conference on System Sciences.
Cohen-Cline, H., Turkheimer, E., Duncan, G.E., 2015. Access to green space, physical activity and mental health: a twin study. J. Epidemiol. Community Health 69 (6), 523–529.
Colding, J., Barthel, S., 2013. The potential of 'Urban Green Commons' in the resilience building of cities. Ecol. Econ. 86, 156–166.
Colding, J., 2007. 'Ecological land-use complementation' for building resilience in urban ecosystems. Landsc. Urban Plan. 81 (1–2), 46–55.
de Jong, M., Joss, S., Schrawen, D., Zhan, C., Weijnen, M., 2015. Sustainable-smart-resilient-low carbone-eco-knowledge cities; making sense of a multitude of concepts promoting sustainable urbanization. J. Clean. Prod. 109, 25–38.
Dempsey, N., Brown, C., Bramley, G., 2012. The key to sustainable urban development in UK cities? The influence of density on social sustainability. Prog. Plan. 77, 89–141.
Elmqvist, T., Folke, C., Nyström, M., Peterson, G., Benktsson, J., Walker, B., Norberg, J., 2003. Response diversity, ecosystem change, and resilience. Front. Ecol. Environ. 1 (9), 488–494.
Findahl, O., 2013. En Miljon Svenskar Vill Inte Använda Internet. En Rapport Om

Digital Delaktighet. Digidel,.SE (Stiftelsen för internetinfrastruktur), Stockholm.
Folke, C., Jansson, Å., Rockström, J., Olsson, P., Carpenter, S.R., Chapin, F.S., Crépin, A.-S., et al., 2011. Reconnecting to the Biosphere. Ambio. 40 (7), 719–738.
Giusti, M., Barthel, S., Marcus, L., 2014. Nature routines and affinity with the Biosphere: a case study of preschool children in Stockholm. Child. Youth Environ. 24 (3), 16–42.
Grimm, N.B., Faeth, S.H., Golubiewski, N.E., Redman, C.L., Wu, J., Bai, X., et al., 2008. Global change and the ecology of cities. Science. 319, 756–760.
Hartig, T., Kahn Jr., P.K., 2016. Living in cities, naturally. Science 352 (6288), 938–940.
Hartig, T., Mitchell, R., de Vries, S., Frumkin, H., 2014. Nature and health. Annu. Rev. Public Health 35, 207–228.
Hollands, R.G., 2008. Will the real Smart City stand up? Intelligent, progressive or enterpreneurial? City 12 (3), 303–320.
Hollands, R.G., 2015. Critical interventions into the corporate smart city. Camb. J. Reg. Econ. Soc. 8, 61–77.
Ives, C.D., Giusti, M., Fischer, J., Abson, D.J., Klaniecki, K., Dorninger, C., Laudan, J., Barthel, S., Paivi, A., Berta Martín-López, B., Raymond, C., Kendal, von Wehrden, H., 2017. Human-nature connection: a multidisciplinary review. Opin. Environ. Sustain. accepted for publication. PII: S1877-3435(17)30126-4.
Kaiser, F.G., Brügger, A., Hartig, T., et al., 2014. Appreciation of nature and appreciation of environmental protection: how stable are these attitudes and which comes first? Rev. Eur. Psychol. Appl. 64, 269–277.
Levin, S.A., 2000. Fragile Dominion: complexity and the Commons. Perseus Publishing, Cambridge, USA.
Levin, S., Xepapadeas, T., Crépin, A.-S., Norberg, J., de Zeeuw, A., Folke, C., Hughes, T., Arrow, K., Barrett, S., Daily, G., Ehrlich, P., Kautsky, N., Mäler, K.-G., Polasky, S., Troell, M., Vincent, J.R., Walker, B., 2012. Social-ecological systems as complex adaptive systems: modeling and policy implications. Environ. Dev. Econ. 1–22. http://dx.doi.org/10.1017/S1355770X12000460.
Lewis, J., 2015. Deltaic Dilemmas-ecologies of Infrastructure in New Orleans. PhD-thesis Stockholm University. Stockholm Resilience Centre. ISBN 978-91-7649-239-0. http://urn.kb.se/resolve?urn=urn:nbn:se:su:diva-119390.
Luque-Ayala, A., Marvin, S., 2016. Developing a critical understanding of smart city urbanism? Urban Stud. 52 (12), 2105–2116.
Makrushin, D., Dashchenko, V., 2017. Fooling the Smart City. Securing Smart Cities. Kaspersky Lab. Available online: http://securingsmartcities.org/wp-content/uploads/2016/09/Fooling-smart-city_in_template.pdf (Accessed 21 April 2017).
March, H., Ribera-Fumaz, R., 2016. Smart contradictions: the politics of making Barcelona a self-sufficient city. Eur. Urban Reg. Stud. 23 (4), 816–830.
March, H., 2016. The smart city and other ICT-led techno imagaries: any room for dialogue with Degrowth? J. Clean. Prod. http://dx.doi.org/10.1016/j.jclepro.2016.09.154 (in press).
May, R.M., Levin, S.A., Sugihara, G., 2008. Complex systems: ecology for Bankers. Nature 451, 893–895.
Marcus, L., Koch, D., 2016. Cities as implements or facilities – the need for a spatial morphology in smart city systems. Environ. Plan. B Urban Anal. City Sci. 1–22. http://dx.doi.org/10.1177/0265813516685565.
Mayer, F., Frantz, C., 2004. The connectedness to nature scale: a measure of individuals' feeling in community with nature. J. Environ. Psychol. 24, 503–515.
McPhearson, T., Andersson, E., Elmqvist, T., Franzeskaki, N., 2015. Resilience of and through urban ecosystem services. Ecosyst. Serv. 12, 152–156.
Meijer, A., Rodriguez Bolivar, M.P., 2016. Governing the smart city: a review of the literature on smart urban governance. Int. Rev. Adm. Sci. 82, 392–408.
Miller, J., 2005. Biodiversity conservation and the extinction of experience. Trends Ecol. Evol. 20, 430–434.
Missimer, M., Robért, K.-H., Broman, G., 2017. A strategic approach to social sustainability - Part 1: exploring the social system. J. Clean. Prod. 140, 32–41.
Naphade, M., Banavar, G., Harrison, C., Paraszczak, J., Morris, R., 2011. Smarter cities and their innovation challenges. Computer 44 (6), 32–39.
Newman, P.W.G., 1999. Sustainability and cities: extending the metabolism model. Landsc. Urban Plan. 4 (1), 219–226.
Nutsford, D., Pearson, A.L., Kingham, S., Reistma, F., 2016. Residential exposure to visible blue space (but not green space) associated with lower psychological distress in a capital city. Health Place 39, 70–78.
Prop. 2016-Regeringens Proposition, 2016. Forskning I Samverkan-för Samhällets Utmaningar Och Stärkt Konkurrenskraft. Prop. 2016/17:50.
Raymond, C., Giusti, M., Barthel, S., 2017. An embodied perspective on the co-production of cultural ecosystem services: toward embodied ecosystems. J. Environ. Plan. Manag. http://dx.doi.org/10.1080/09640568.2017.1312300.
Rees, E.W., 1992. Ecological footprints and appropriated carrying capacity: what urban economies leaves out. Environ. Urban. 4 (2), 121–140.
Restall, B., Conrad, E., 2015. A literature review of connectedness to nature and its potential for environmental management. J. Environ. Manag. 159, 264–278. http://dx.doi.org/10.1016/j.jenvman.2015.05.022.
Seto, K.C., Guneralp, B., Hutyra, L.R., 2012a. Global forecasts of urban expansion to 2030 and direct impacts on biodiversity and carbon pools. PNAS 109 (40), 16083–16088.
Seto, K.C., Reenberg, A., Boone, C.G., et al., 2012b. Urban land teleconnections and sustainability. PNAS 109, 7687–7692.
Soga, M., Gaston, K.J., Koyanagi, T.F., Kuriso, K., Hanaki, K., 2016. Urban residents' perceptions of neighbourhood nature: does the extinction of experience matter? Biol. Conserv. 203, 143–150.
Thompson, C.W., Roe, J., Aspinall, P., et al., 2012. More green space is linked to less stress in deprived communities: evidence from salivary cortisol patterns. Landsc. Urban Plan. 105 (3), 221–229.
Thomas, C.D., Cameron, A., Green, R.E., et al., 2004. Extinction risk from climate change. Nature 427, 145–148.
U.N, 2014. United Nations - World Urbanization Prospects: the 2014 Revision. United Na- tions, Department of Economic and Social Affairs, Population Division, New York. Available at: www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html. Accessed April 2017.
U.N, 2015. United Nations - World Population Prospects. Volume 1: Comprehensivbe Tables. Available at: https://esa.un.org/unpd/wpp/publications/Files/WPP2015_Volume-I_Comprehensive-Tables.pdf. Accessed April 2017.
UN-Habitat, 2016. World Cities Report 2016. Urbanization and Development – Emerging Futures. United Nations Human Settlements Programme (UN-Habitat). ISBN Number (Volume): 978-92-1-132708-3. Available online: http://wcr.unhabitat.org/wp-content/uploads/sites/16/2016/05/WCR-%20Full-Report-2016.pdf. Accessed April 2017.
Van Bastelaer, B., 1998. Digital cities and transferability of results. In: In the Proceedings of the 4th EDC Conference on Digital Cities.
Waters, C.N., Zalasiewicz, J., Summerhayes, C., et al., 2016. The Anthropocene is functionally and stratigraphically distinct from the Holocene. Science 351 (6269). http://dx.doi.org/10.1126/science.aad2622. PMID 26744408.
Webber, M.M., 1963. Order, diversity: community without propinquity. In: Wingo, L. (Ed.), Cities and Space: the Future Use of Urban Land. John Hopkins University Press, Baltimore, pp. 23–54.
Zanella, A., Bui, N., Castellani, A., Vangelista, L., Zorzi, M., 2014. Internet of things for smart cities. Ieee Internet Things J. 1 (1).
Zylstra, M.J., Knight, A.T., Esler, K.J., Le Grange, L.L., 2014. Connectedness as a Core Conservation Concern: an Interdisciplinary Review of Theory and a Call for Practice. Springer Science Reviews, pp. 119–143. http://dx.doi.org/10.1007/s40362-014-0021-3.

Internet:

Giddens, A., 2016. Social Europe. Podcast #10. https://www.socialeurope.eu/podcast/.

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