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Conceptualizing "Smart Cities"

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"Smart City" has become a buzzword. Much is being written about smart cities as we speak, most of it promotional and uncritical [5, 14]. The goal of this article is not to criticize smart cities, nor is it to promote them. Rather, we would like to make a contribution to the conceptualization of smart cities and, by doing so, help the concept to become intellectually more solid. We think that this will also contribute to developing a more realistic and ultimately more practical view of what smart cities can achieve … and what they cannot.

In this article, we will proceed along the following five steps: in a first step, we will conceptualize cities as complex and dynamic socio-technical systems, a conceptualization without which "smart cities" – i. e., the penetration of cities by the information and communication technologies (a phenomenon also called digitalization) – cannot really be understood. In a second step, we will then define such digitalization much more precisely. Such a definition will be necessary in order to understand, in a third step, what digitalization exactly does to cities. In a fourth section, we will then discuss what such digitalization means for cities. In a fifth section, we will further elaborate on this and discuss the different perspectives on smart cities made possible by the digitalization of urban systems.

Conceptualizing Cities

Before conceptualizing smart cities, it is imperative to conceptualize cities. This is necessary because the intellectual confusion already starts there: although many academics have studied and written about cities, all this work has been disciplinary-based, leading each time to a very partial and overall fragmented view on what cities are, how they function, and how they should be made to function. Most prominently, cities have been the object of study by *sociologists* – mainly concerned with the life and interactions in cities –, urban *planners* – mainly concerned with the development and use of land –, *architects* – mainly concerned with buildings and larger physical structures –, civil *engineers* – mainly concerned with the construction and at times operations of the urban infrastructures –, *economists* – mainly concerned with spatially bounded economic activities and city competitiveness –, *public administrators* – mainly concerned with the day-to-day management of city affairs –, *political scientists* – mainly concerned with city governance, and *information systems researchers*, mainly concerned with "smart cities" and focusing on the analysis of data in an urban context. Only very recently have we been able to observe the emergence of a more integrative view on cities, influenced mainly by systems theory [4, 25]. However, this so-called "*New Science of Cities*" remains quite abstract and relatively unrelated to the above dimensions of a city.

We instead propose a conceptualization of cities as a complex and dynamic socio-technical system, which we think more appropriate and more practical than the above partial or too abstract conceptualizations. This conceptualization is rooted in the tradition called STS – Science, Technology, and

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***Fig. 1** Cities as complex and dynamic socio-technical systems*

Society – and posits a strong interaction between Society on the one hand and Science and Technology on the other [19, 31]. More recently, this STS approach has been put into the context of innovation and institutional theory, therefore leading to a more dynamic view about the co-evolution between technology and society [8, 9]. Finger et al. applied this approach more specifically to the dynamic interaction between society and infrastructures at the national level, referring in particular to the intellectual tradition of institutional economics [7]. However, all this literature basically taking the nation-State as the relevant unit.

The originality of our approach lies in the fact that we apply this approach of complex and dynamic socio-technical systems to cities. More precisely, we take large urban systems – which are agglomerations or *metropolitan areas*, rather than cities – as the relevant unit. In other words, large urban systems are, on the one hand, physical places where people live and work together; while on the other urban infrastructure systems (transportation, energy, water and wastewater, housing, telecommunications, and green infrastructures) create and determine the very conditions of such living together. These urban infrastructure systems are in turn of course also shaped by the city's environment, urban society, the urban economy and the institutions in place, thus forming one dynamic socio-technical system [12, 13, 21, 30]. Figure 1 summarizes our approach.

This way of conceptualizing cities or rather urban systems has of course a series of implications, notably for their management and their governance. Many of these implications have already been identified by the above-mentioned "New Science of Cities" [4]: let us mention the most important implications here, namely the nonlinear evolution (dynamics) of urban systems, resulting from their complexity and the multiple interactions and feedback loops among the different subsystems and actors. At the same time, the evolution of such urban systems is of course path dependent. Let us also mention the fact, that urban systems are, by their very nature, never in equilibrium and many behaviors of both actors and subsystems will be both unpredictable and emergent.

These characteristics of metropolitan areas as complex and dynamic socio-technical systems precede and are of course independent of the Information and Communication Technologies (ICTs). However, we think that this conceptualization allows for a much more appropriate understanding of the role these ICTs will come to play in cities, once systematically deployed. In other words, we posit that "smart cities" – *which we define as the systematic application to and pervasive penetration of cities by the ICTs* – cannot be understood properly if cities are not conceptualized as socio-technical systems. But before presentation of what the ICTs (or digitalization) do to cities, let us first clarify what digitalization exactly is.

What is Digitalization?

As a next step, we need to understand "digitalization," as smart cities are – at least in our view – a combination of urban infrastructure systems on the one hand and digitalization, on the other. In this section we will therefore explain the three main building blocks of digitalization, namely data generation, data connection, and data analysis. Only in the next section will we then examine what digitalization exactly does to cities.

Data are *generated* from numerous sources such as (digital) cameras, sensors, RFIDs, satellites, and many other technical devices about ever more things. Not only is the number of data-collecting devices increasing exponentially, but moreover these devices are increasingly active both round the clock and the year. Also, data are more and more generated by the users themselves by way of their smartphones, either through deliberate postings or simply because the devices record information automatically. More recently, thanks to the phenomenon called "Internet of Things" (IoT), data are generated by the different "things" themselves, which are connected to the internet via the World Wide Web [3]. In short, the amount of data generated is growing exponentially, both in cities and everywhere else.

The second building block of global digitalization is the "Internet," which acts as an *infrastructure*, upon which the World Wide Web has been developed during the past few years. Later on in this article, we will call this the "data layer." The World Wide Web is the global information space from where data/documents (so-called web resources) can be identified thanks to URLs (Uniform Resource Locator = web addresses) and exchanged thanks to hypertext links (HTML = Hypertext Markup Language). The Internet, in turn, is the global system of computers connected to each other thanks to the global physical communication network (fiber, satellites, mobile towers, etc.) as well as thanks to the so-called TCP/IP protocol. In short, the World Wide Web and the Internet combined make all these data globally available and accessible.

The third building block of digitalization pertains to the *capacity to deal with these huge amounts of data*. Not only is computing power increasing exponentially, but so are the transmission and storage capacities of such data. Simultaneously, the prices and therefore the affordability of computers, transmission, and storage decrease also exponentially[1]. But what is really new is the rapid development of the analytical skills, i. e., the available intelligence, to analyze these exponentially growing amounts of data, leading to new ways of analyzing and visualizing these data, a phenomenon called "big data" [20].

[1] This trend was observed in a seminal article by Gordon E. Moore in 1965 and is often referred to as Moore's law [22].

Digitalizing Urban Systems

So far we have conceptualized cities, or rather metropolitan areas, as dynamic socio-technical systems and we have identified the three major building blocks of digitalization. In this section, we now bring these two together to define what, in our view, "digital or digitalized urban systems" exactly are. We will also use the word "smart cities" for such digital urban systems. However, we think that our way of defining smart cities as socio-technical systems undergoing digitalization is intellectually more rigorous than the buzz word "smart cities." Ultimately, as we will show later, our definition will also prove to be more practical. We will proceed in three steps, applying systematically the three building blocks of digitalization to urban infrastructure systems.

To recall, the first building block of digitalization is *data generation*. Applied to urban infrastructure systems, this means equipping the different infrastructures (and their users) with sensors, cameras, RFIDs and many other data gathering devices, so as to collect data, for example, from the green (e. g., trees, parks), the blue (e. g., water pipes), or the grey infrastructures (e. g., disposable and disposed waste, wastewater pipelines, wastewater treatment plants). Similarly, data can be collected from buildings (for example about their energy consumption) energy grids (electricity, gas), as well as transportation infrastructures (tracks, roads, toll stations), vehicles (cars, buses, trains, metros, trams, bikes), and even users themselves. In short, urban infrastructure systems offer – thanks to this first building block of digitalization – unprecedented opportunities for generating data on just about everything that can be measured.

The second building block of digitalization is the global *infrastructure* in the form of the World Wide Web and the Internet. In the context of urban systems, we will call this infrastructure the "data layer." This urban data layer is composed of several elements. Like in the case of the global Internet, the urban data layer has first a purely physical component: indeed, the various data-generating devices will have to be connected (via a physical telecommunications line or via a mobile connection to a physical data repository (typically a server)). For these data to be accessible and ultimately usable, they will have to follow certain standards. It is also possible to avoid such a dedicated physical data repository by connecting these various data-generating devices directly to the global Internet, thus avoid-

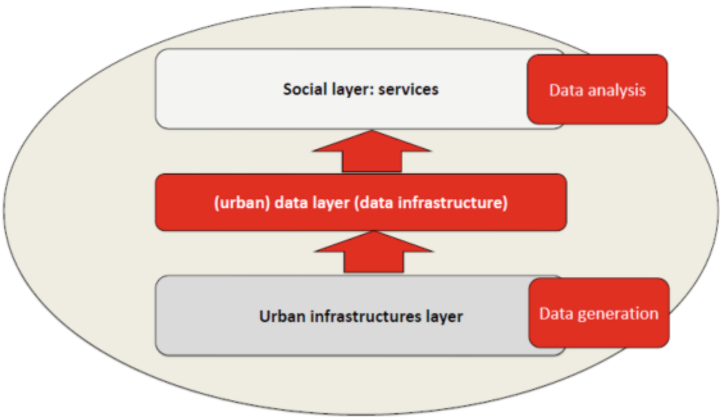

Fig. 2 Our conceptualization of a smart city

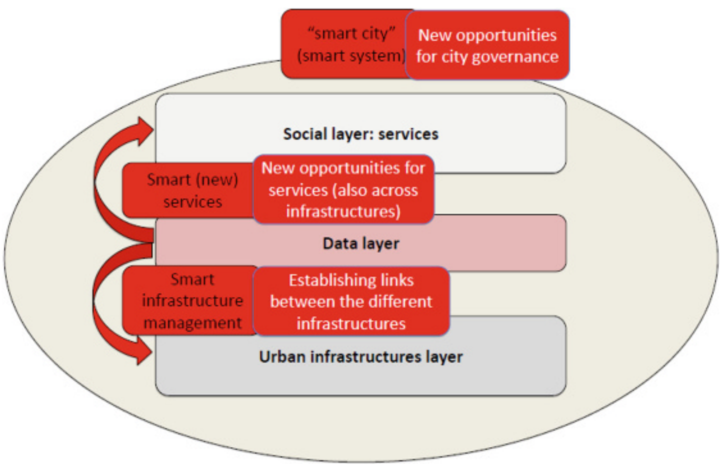

Fig. 3 Implications of digitalization of cities

ing the standardization question and accessibility questions altogether. The third and probably most likely possibility is to connect the data generating devices to a (intermediary) data repository, which then is connected to the global Internet and accessible (at least in part) via the World Wide Web. The main issue here is whether this data layer is proprietary or openly accessible. As Townsend (2013) discussed, the bottom-up approaches to developing "collaborative networks" could be a significant rival to the "proprietary monopolies" in the near future [29, p. 9].

The third building block of digitalization is *data analysis*. Applied to urban infrastructure systems, this means making something from the data. This on the one hand raises the question of the ability to analyze the data and on the other the question why are these data being analyzed, i. e., for commercial or for noncommercial purposes. Typically, the analysis of such data will lead to (new) services, that can either pertain directly to the usage of the urban infrastructure systems (e. g., mobility pricing) or indirectly as in the case of location-based offers to users. Sometimes, such services are also called "smart (city) services."

Figure 2 summarizes the application of digitalization to urban systems, and as such constitutes our basic conceptualization of our conceptualization of a smart city.

Implications of Digitalization for Cities

In this section, we will discuss what digitalization means – and potentially could mean – for cities. This potential, we will argue, goes much further than what the current concept of "smart city" implies. Concretely, we identify three such implications, namely first the implication for the management of urban infrastructure systems, second the implications for urban services, and third the implications for the governance of metropolitan areas more generally. Figure 3 summarizes these three types of implications.

Implications for the management of urban infrastructure systems: mainly the first and second building blocks of digitalization combined have direct implications for the day-to-day operations and management of urban infrastructure systems, mainly in terms of their efficiency. Indeed, the numerous data collected by the various generating devices significantly contribute to operating and more generally managing urban infrastructures as systems and therefore contribute to operating and managing them more efficiently. This is typically the case of urban electricity systems, something which has been called a "smart grid" [11]. But similarly you can apply this approach to water and wastewater ("smart water"), waste ("smart waste", i. e., recycling), buildings ("smart buildings"), and transport ("smart transport") (e. g. [16, 26]). In addition, there is also, thanks to digitalization, the ability to link the operations and management of the different urban infrastructure systems in a more systemic approach, something which has been called the (urban) "circular economy" [10], a concept which actually builds on the predigitalization concept of "industrial ecology" [17]. As a matter of fact, this more efficient operation and management of urban infrastructure systems taken either separately or, more rarely, as a whole currently constitutes the dominant definition of "smart cities" [1, 15, 24].

Implications for (new) urban services: especially the third building block of digitalization (new services) has huge implications for cities. Indeed, thanks to the numerous data generated, and especially thanks to their analysis (and display; e. g., big data), it is possible to offer new services, most of which stem from the fact that data are gathered and analyzed across modes. This is for example the case of data analyzed across transportation modes, leading to something today called "mobility-as-a-service" [27], but also "mobility pricing" [6], or more generally for data analyzed across different infrastructure sectors such as the intersection between the energy and housing infrastructures which is known as "smart homes" [2]. Typically, such services will be offered commercially or, if they are not, must have other underlying business models.

The third type of implications of digitalization for cities pertains to city governance: obviously, the generation of all these data from the various urban infrastructures can lead to more than making them more efficient (smart city) or to generating new (cross-modal) urban services. Even though there are far fewer examples available, digitalization offers completely new and unprecedented opportunities for governing urban systems, notably in terms of citizens' participation and more generally involvement of nongovernmental actors in collective decision-making and management [23]. Examples of such initiatives can be found in very limited bottom-up governance experiments to collect citizens' points of view about specific issues by using smart phones as a supplementary public consultation strategy (see for example [18]). However, this potential for digitalization to be used in the governance of metropolitan areas has, unfortunately, so far been under-unexplored[2]. Yet, potentially, this will lead to much more than making cities more efficient and will, in the end, also require a concept other than "smart city" to adequately account for this new phenomenon.

Perspectives on Smart Cities

As stated in the Introduction, "smart city" has become a buzzword. In this section, we will also show that it is above all a promotional concept, i. e., a concept which still will have to be appropriated by cities themselves. Our conceptualization of smart cities as the application of digitalization (three building blocks) to urban infrastructure systems also offers a better understanding of the various interests in promoting "smart cities," a promotion which has been mostly pushed, so far, by various types of vendors. In this section, we will distinguish between the perspectives of four types of vendors and one type of urban actor, namely urban utilities. This is not to say that the vendors' perspectives are not legitimate; rather, we will argue here that their various perspectives are partial and ultimately do not exhaust the potential of digitalization for cities. To this end, we will, in conclusion of this section, oppose the perspective of the city or metropolitan area itself. Figure 4 summarizes these six possible perspectives on smart cities.

There is first the perspective of the different *hardware vendors*: such vendors sell sensors, cameras, and many other monitoring and data-generating devices, such as smartphones, which can be

[2] It is important to note that currently, analysis of data from secondary sources (such as Twitter and other social medias) is being used by some local and national governments to get a better understanding of social trends, but such initiatives are different from effective use of technology to enhance citizens' participation in the process of governance.

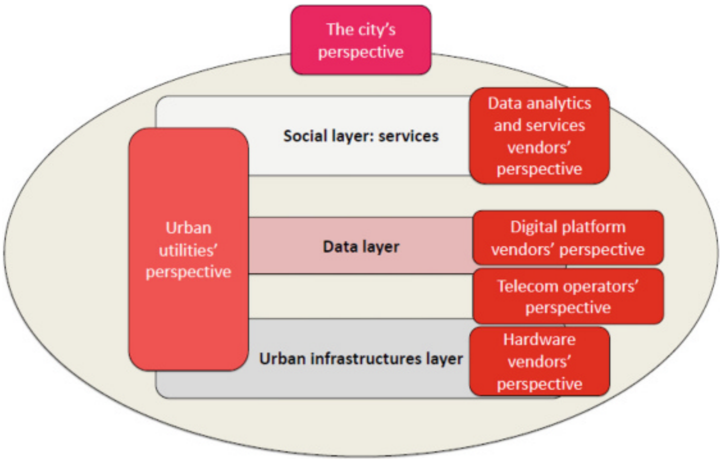

***Fig. 4** Six perspectives on smart cities*

generic (e. g., user-generated data) or specific to one infrastructure (e. g., smart meters in the case of electricity or gas). These devices can be sold to individuals (e. g., smart meters, smartphones), utilities (e. g., smart meters), or cities (e. g., traffic cameras). However, the reason why these types of vendors are promoting the concept of smart cities also lies in the fact that they, ultimately, hope to also make money from the data they so generate, i. e., ultimately will be able to offer smart services, where value-added will be much greater.

There is secondly the perspective of the *telecommunications operators*: telecommunications operators are typically intermediaries that connect the data-generating devices either directly to the Internet or to some sort of digital platform. They are not vendors per se, as they predate the smart city phenomenon. However, as intermediaries they have access to huge amounts of data, which they hope to ultimately monetize by turning these data into smart city services for individuals. As an intermediary step, they may become active in operating and selling data platforms to cities.

There is thirdly the perspective of (digital) *platform operators*: these are typically companies that own and operate physical servers and ICT-platforms more generally (hardware), in most cases for firms, such as banks, retailers, logistics companies, and others. Their interest in promoting the concept of smart city lies in the fact that they would like to also sell such platforms to urban utilities and city governments. They may also want to move into offering smart city services, given that they have access to all this data.

There is fourthly the perspective of *data analytics companies*: these companies, by virtue of their expertise in analyzing (and displaying) (big) data, are able to make such data value-added and therefore commercially interesting services for users, which can be individuals (e. g., e-hailing services), other firms (e. g., consumer behavior analysis), or cities (e. g., traffic analysis). This is probably the most lucrative segment of the entire "smart city value chain," which is why all previously mentioned vendors ultimately also want to move into this segment of the value chain.

The fifth perspective on smart cities is slightly different and stems from *urban utilities*: urban utilities typically operate urban infrastructures, such as (more or less integrated) transportation, electricity, gas, water, wastewater, district heating, waste disposal systems etc. In the context of digitalization, they are now equipping their infrastructure systems with all kinds of data-generating devices, which enables them to potentially offer smart city services, provided, however, they are capable of analyzing these data and turn them into services that individuals, other firms, or city administrations are willing to pay for. This perspective in fact also applies to logistics companies, postal operators, and retail chains which can also equip their operations with data-generating devices, thus creating what is called the "Internet of Things" (IoT), and, by doing so develop and commercialize (smart city) services, again for individuals (e. g., track and tracing), other firms (e. g., customer insights), or city administrations (e. g., pollution measurements).

All five perspectives detailed above contrast, at least in principle, with the perspective of a city or more appropriately of a metropolitan area itself. The main difference pertains to the fact, that all above-mentioned operators will ultimately pursue a commercial interest, even though public operators such as public urban utilities may have slightly less financial pressure. This leads them to develop services that can either be directly monetized by selling them to individuals or firms or services that help cities (or firms) become more efficient, thus saving on costs. This is precisely why the concept of smart cities as promoted by the different vendors – the five types of operators noted above – is heavily associated with efficiency only. In other words, for all the above-noted operators, smart cities equal efficient cities. While this observation does not constitute, in itself, a criticism of the concept of smart city, we nevertheless argue that there is more to digitalization of urban systems than efficiency gains, and making money for that matter.

And this is precisely where the perspectives of the *city*, the *metropolitan area* and, most importantly, their *inhabitants* come in: while their perspectives certainly also pertain to efficiency – i. e., more efficient cities thanks to the digitalization of their urban infrastructure systems –, they may want to pursue (in addition to efficiency) also other (performance) objectives, such as more sustainable and more resilient urban systems, leading ultimately to a better quality of city life. Unfortunately, these perspectives remain, so far, underdeveloped – as compared to the other five perspectives. In other words, the citizens, the nongovernmental organizations, civil society more generally, as well as city administrators and especially city politicians have not yet fully appropriated what digitalization of urban infrastructure systems does and, potentially, could or could not mean for them.

Conclusion: What is at Stake in the Evolution Towards Smart Cities?

Let us, therefore and in conclusion, outline what issues are in our opinion at stake in this process of digitalizing cities, or more precisely urban infrastructure systems, i. e., the phenomenon which has been labelled "smart city." In our opinion three such issues can and should be identified: technology push or demand pull, consumers or citizens, and leadership.

The phenomenon of digitalization is not new and can be traced back to the late 1970s when the first publications concerning the "digital revolution" – the Third Wave [28] – appeared. However, concrete and significant economic and social consequences of digitalization appeared only at the turn of the century, and have accelerated ever since. "Smart city" is but the last expression of this technological revolution (digitalization), which we have decomposed, above, into three separate building blocks (data generation, infrastructure, and analysis). However, here arises the first issue at stake for the smart city phenomenon and for digitalization more generally: *technology push or demand pull?* Will smart cities continue, as is currently the case, being pushed into the rapid development of information and communication technologies or are cities and their inhabitants capable of formulating their "demands" in a way that technology will ultimately serve their needs?

The second issue at stake follows quite logically from the first: *consumers or citizens?* Quite clearly, the various operators promoting smart cities today pursue commercial interests. In the context of the financial constraints, if not financial crisis of the public sector, this however means that most of these operators ultimately aim at developing (smart city) services that they can sell to consumers, rather than services that are in the public interest. The latter may not be as lucrative, yet citizens, cities and metropolitan areas may need them (perhaps more urgently). However, in the absence of a financially solid public sector at the city and metropolitan area level, such services may never be developed.

And from here follows the last issue at stake, namely the question of *leadership*: rather than being driven by technology and technology vendors, civil society actors and their political representatives should appropriate digitalization and place the concept of smart cities within the context of broader public policy objectives, whereas efficiency may well and actually should be one – but not the only (as is currently the case) – of these policy objectives. This, in turn, raises the issue of how to govern the smart city in the public interest (once in place), but, more importantly and more urgently, how to govern the transition from the current urban legacy systems to smart urban systems … as it may well be too late, once these systems are in place (smart city lock-in).

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