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Assembling Sustainable Smart City Transitions: An Interdisciplinary Theoretical Perspective

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Abstract: This Special Issue begins with a middle-range theory of sustainable smart city transitions, which forms bridges between theorizing in smart city development studies and some of the foundational assumptions underpinning transition management and system innovation research, human geography, spatial planning, and critical urban scholarship. This interdisciplinary theoretical formulation details our evidence-based interpretation of how smart city transitions should be conceptualized and enacted in order to overcome the oversimplification fallacy resulting from corporate discourses on smart urbanism. By offering a broad and realistic understanding of smart city transitions, the proposed theory combines different smart-city-related concepts in a model which attempts to expose what causal mechanisms surface in sustainable smart city transitions and to guide empirical inquiry in smart city research. Together with all the authors contributing to this Special Issue, our objective is to give smart city research more robust scientific foundations and to generate theoretical propositions upon which subsequent large-scale empirical testing can be conducted. With the proposed middle-range theory, different empirical settings can be investigated by using the same analytical elements, facilitating the cross-case analysis and synthesis of the systematic research efforts which are progressively contributing to shading light on the assemblage of sustainable smart city transitions.

Keywords: Sustainable smart city transitions, middle-range theory, theoretical model, conceptualization, interdisciplinarity

1. Smart city development, transitions studies, and the sustainability of urban sociotechnical systems

Challenging the conventional thinking embedded in the current urban development pathways is crucial in establishing a new science of cities (Batty, 2013a). This science must embrace global sustainability principles (Reid et al., 2010) and inform society on how socioeconomic development goals can be met while mitigating the environmental risks and other pressing societal challenges affecting urban spaces. The process of fostering urban sustainability starts with a rearrangement of our urban environments and the ways we address the provision of urban services. Urban environments comprise a multitude of interrelated sociotechnical systems (Batty, 2005, 2009), which provide urban communities with the services required to address societal needs. Housing, transportation, energy, waste management, healthcare, telecommunication, and education, are all examples of sociotechnical systems assembled to serve urban spaces. When urban environments fail to satisfy societal needs in a sustainable manner, sustainability transitions begin to unfold: "long-term, multi-dimensional and fundamental transformation processes through which established sociotechnical systems shift to more sustainable modes of production and consumption" (Markard et al., 2012: 956).

In an effort to sustain such transitions, cities have begun to propose strategic responses whose objective is to reorganize the functioning and evolutionary processes of "urban sociotechnical systems" (Patorniti et al., 2018: 294). As a result, urban spaces have become major hubs of sustainability-oriented experimentations (Ehnert et al., 2018) and key sites of sustainability transitions (Bulkeley et al., 2016a, Frantzeskaki et al., 2017, Nagorny-Koring and Nochta, 2018).

With the emergence of sustainability transitions in urban settings, systemic thinking has started penetrating sustainable urban development strategies. Hodson and Marvin (2010) explore this new combination in a study entitled "Can cities shape sociotechnical transitions and how would we know if they were?". To answer these questions, the authors focus on a group of large cities (London, New York, Tokyo, San Francisco and Melbourne) and analyze a number of strategic attempts to use systemic thinking for enhancing the sustainability of urban service provision. Conducted in the framework of sociotechnical transition theories, this study was one the first to examine how sustainability transitions and system innovation processes organize themselves in urban environments, and it has contributed to opening up the new and as yet unexplored research area of urban sustainability transitions (Hansen and Coenen, 2015, Truffer and Coenen, 2012).

The contribution offered by Hodson and Marvin has powered a new stream of research which criticizes the early literature on transition management for both the absence of geographically sensitive conceptualizations (Raven et al., 2012, Truffer et al., 2015) and an excessive national-centric focus (Ehnert et al., 2018). This research has also been instrumental in strengthening the cross-disciplinary collaboration between urban studies and sustainability transition studies. Additionally, it has enriched transition theory by exposing the critical role that spatial and geographical factors play in the shaping of transition dynamics for sustainability. Urban sustainability transitions require differentiating between transnational (Manning and Reinecke, 2016), national (Bridge et al., 2013, Geels et al., 2016), regional (Späth and Rohracher, 2010), and city level, whose governance structures should be considered as discrete units of analysis (Murphy, 2015).

This elaboration of cities as "engines of change" (Castán Broto, 2015: 462) is particularly evident when observing the academic debate on low carbon transition dynamics. A growing body of research reports on city-led climate change experiments which are now available to accelerate the transition to low-carbon systems (see Bulkeley and Castán Broto, 2013, Evans et al., 2016, Kivimaa et al., 2017). By looking into these experiments, it is evident that transition research is developing the evidence-based knowledge which is needed to show how urban sustainability transitions should be managed. Some noteworthy elements which have been investigated include contextual barriers sustaining resistance to change (Nagorny-Koring and Nochta, 2018), organizational dynamics and governance structures for regulating the transformation (Eames et al., 2013, Hodson and Marvin, 2012, North and Longhurst, 2013), the practical implications of institutional tensions and contradictions (Castán Broto, 2015, Fuenfschilling and Truffer, 2014), and the challenges that controlling urban sustainability transitions in suburban expansions pose (Dodson, 2014, Petrova et al., 2013).

Notwithstanding the growing interest of sustainability transition studies in the urban context (Fuenfschilling et al., 2019), we have noticed that a lack of scholarly engagement surfaces when looking for contributions examining smart city discourses in the framework of transition studies (Carvalho, 2015, Mora and Deakin, 2019, Raven et al., 2019, Simmons et al., 2018).

We believe that this lack is of concern because smart city development should be considered as the outcome of a sociotechnical transition process (Deakin, 2014). Building on this rationale, smart cities should be interpreted as urban environments engaged in a context-dependent, multi-dimensional, and systemic transformation process through which the sustainability of their sociotechnical systems for urban service provision is enhanced by adopting smart city technologies (such as smart grids, emergency management systems, intelligent transport solutions, eHealth technologies, etc.) (Mora and Deakin, 2019).

Smart city development exposes the coevolutionary nature of technology and society, as well as the systemic character of innovation (Leydesdorff and Deakin, 2011). Bringing new technologies into society is not sufficient to improve urban sustainability. For this goal to be achieved, a sociotechnical transition path must be created through complementary actions, whose cumulative effects make it possible to replace a stabilized technological trajectory with a new configuration that works. Smart cities boost the change towards more sustainable urban futures by adopting smart city technologies with potential for urban sustainability enhancement and by creating the conditions in which these new technologies and existing local practices can mutually adapt.

During this transformation process, that we call *smart city transition*, the sociotechnical systems of a urban environment are subject to multi-dimensional changes which enable the introduction of smart city technologies into the urban infrastructure. Existing configurations are replaced with new sociotechnical arrangements which allow for the newly introduced digital technologies to be effectively deployed, and the usage of such technologies should enhance the ability of urban services to meet societal needs in a sustainable manner. As part of these transitions, for example, digital platforms have emerged in diverse types of urban sociotechnical systems, all building on internet technologies, and they are expanding the range of information functions that power our everyday activities (Mcafee and Brynjolfsson, 2017; Schaffers et al., 2011). Increased socio-economic and environmental sustainability, along with an improved quality of urban life, are the benefits that smart city transitions are expected to generate (Mora et al., 2017). However, as we will point out in the following section, this is not always the case.

2. Assembling sustainable smart city transitions: theoretical and practical shortcomings

Smart city transitions can be considered as a type of urban sustainability transitions and, during the past two decades, they have sought favour with universities, industry, and governments around the world. The importance of these transitions is now also championed by civil society organizations, in particular, the United Nations (UN), whose support for smart city development is found written into both the 2030 Agenda for Sustainable Development and the New Urban Agenda. In these two policy documents, the 193 Member States of the UN point out their commitment to deploying smart city transitions as a digital approach to urban sustainability and clearly suggest harnessing digital technology is key to meet the aspiration which society has to: (1) attain resource efficient, safe, inclusive and accessible urban environments; (2) sustain an economic growth based on the principles of environmental sustainability and inclusive prosperity; and (3) provide equal access for all to public goods and high-quality services.

Policymakers expect the sociotechnical changes triggered by smart city technologies to be crucial in resolving urban sustainability issues. However, the scientific knowledge produced to date falls short of informing design and implementation practice. The community of urban development actors working in the field of smart city transitions has been left without the insight that they need to manage the transformative process in a sustainable manner and ensure that the digital transformation delivers an improved urban sustainability. The theoretical and practical ambiguity which surrounds smart city transitions still leaves many knowledge gaps in what is understood about their assemblage and whether-or-not the benefits lying at the center of these transformations can effectively be delivered (Colding et al., 2020, Kitchin, 2015, Niebel, 2018).

A few academic studies have attempted to offer an overall understanding of smart city transitions and their development process (see Appio et al., 2019, Ben Letaifa, 2015, Harrison et al., 2010, Ibrahim et al., 2018), but their overall theoretical contribution demonstrates that research in this knowledge area remains at a preliminary stage (Lee et al., 2014, Mora et al., 2019a). These research efforts have resulted in a number of conceptual frameworks which seek to explain how smart city transitions take place. However, the proposed frameworks are affected by limitations whose presence has inhibited the identification of a convincing theory from which empirical uniformities can be derived. First, the conceptualization processes build on little or no empirical evidence, and they tend to rely upon an excessive level of abstraction, which does not align with real life conditions. Second, the proposed frameworks fail to offer a systemic view of smart city transitions and struggle to recognize that urban transformations "should be treated as problems of organized complexity", because they push urban sociotechnical systems toward a new state (Patorniti et al., 2018: 282). As a result, not all the change dimensions that sociotechnical transitions involve and not all the necessary levels of analysis are taken into proper account, as well as the pivotal role played by both exogenous and endogenous factors. In addition, causal agency and mechanisms are not theorized. Third, the theoretical assumptions underpinning the frameworks tend to neglect widely accepted theoretical assertions incorporated in broader academic debates related to system innovation and transition management.

Evidence of theoretical inconsistencies is also captured by recent studies exposing the existence of several smart city transition pathways, which propose strategic principles that are divergent in nature. Somewhat opposite recommendations can be found in relation to whether smart city transitions should be implemented by means of a technology-led or holistic strategy and whether they require a double or quadruple-helix model of collaboration, a top-down or bottom-up approach, and a mono-dimensional or integrated intervention logic. The lack of a clear understanding makes it difficult to ensure that urban development actors approach smart city transitions and deploy digital solutions in a way that is capable of delivering urban sustainability (Mora et al., 2017, Mora et al., 2019).

A misguided conceptualization of reality leads to faulty implementation. The evident gap between theory and practice comes to light when observing the effects of 'actually existing' smart city transitions (Shelton et al., 2015). Left without the scientific support they need, a growing number of local governments in both developed countries (Martin et al., 2018) and emerging economies (Datta, 2015, Fromhold-Eisebith and Eisebith, 2019, Watson, 2015), have started to embrace transformative models which mainly relies upon the industry-led approach to smart city development (Kitchin, 2015). As a result of this trend, the responsibility to deliver sustainable smart city transitions has been largely left in the hands of vendors of smart city solutions and their controversial narrative and approach to implementation, which have contributed to creating tension between the smart city concept and sustainable urban development principles.

The industry-led approach to smart city transitions is structured upon a false dawn (Marvin et al., 2016) and a market-oriented storytelling which merges hype with reality (Söderström et al., 2014). Embedded in the techno-utopian understanding (Wiig, 2015) of a "clean and orderly pervasive computing" (Viitanen and Kingston, 2014: 807), vendors of smart city solutions have conceptualized smart city transitions as a neoliberal urban development intervention in which they become urban developers and their one-size-fits-all technologies are sold as the only solution to all sort of urban problems (Luque-Ayala and Marvin, 2015). This interpretation builds on proprietary monopolies (Townsend, 2013) and the interests of business elites (Van Zoonen, 2016) "seeking compliance from a largely passive citizenry" (Bulkeley et al., 2016b: 1711), which is disempowered and marginalized (Martin et al., 2018), and from public administrations who are keen to digitalize urban service but struggle to understand how the transition process should be managed in order to be sustainable (Michelucci et al., 2016). The platform technologies noted above often fall into this trap (Mcafee and Brynjolfsson, 2017). Therefore, as conceived by the corporate sector, smart city transitions are a representation of a speculative rather than sustainable urban future (Leszczynski, 2016).

This one-size-fits-all and techno-led conceptualization has raised significant concerns, generating wide agreement on the need for critical interventions into the corporate approach to smart city transitions (Hollands, 2015). The technocratic vision embedded in the corporate narrative is affected by an "oversimplification fallacy" (Viitanen and Kingston, 2014: 805). It suggests that the materiality of technological solutions take control over implementation and eliminate any non-technological understanding of digital urban transformations. As a result, urban dynamics are unrealistically simplified and smart city transitions become the carrier of a dangerous technological determinism (Voordijk and Dorrestijn, 2019). The corporate-driven interpretation of smart city transitions does not take into account the complex "interrelations between men and things that make up the urban order" (Bulkeley et al., 2016b: 1711) and the importance of sociotechnical configurations of urban systems (Rutherford and Coutard, 2014). It simply argues that the expectations of an improved urban sustainability can be met by introducing some "quick technical fixes" (Valdez et al., 2018: 3385), whose actualization does not require sociotechnical transformation processes. In this vision, smart technologies are considered as "an autonomous force that changes society" (Butt, 2015: 2) and their capability to function and boost urban sustainability do not depend upon non-technological arrangements (Mora et al., 2019).

The corporate approach to smart city transitions sees smart city technologies as an exogenous rather than endogenous factor, without considering that "technological developments and their impacts are multi-actor, non-centered processes" which cannot be controlled by a top-down, centralised elite (Rip and Kemp, 1998: 372). Additionally, this approach relies upon a standardized formula (Paroutis et al., 2014) which separates actualization from geographical scales and time. Smart city transitions are conceived as an instantaneous, ready-to-implement technological upgrade (Mora et al., 2017), rather than an ongoing sociotechnical change process firmly anchored to spatial and temporal dimensions and existing sociotechnical arrangements (Kitchin, 2015, Mora et al., 2019a).

3. A middle-range theory of sustainable smart city transitions

The unfolding, assemblage, and governance mechanisms of sustainability transitions have been widely theorized by means of different analytical frameworks, but limited attention has been given to smart city transitions. These frameworks have originated from the introduction of complex systems theories and evolutionary theories in science and technology studies (Genus and Coles, 2008). According to Markard et al. (2012), the analytical frameworks which have acquired the highest scientific value include the transition management policy model (Loorbach, 2010), the strategic niche management framework (Kemp et al., 1998), the technological innovation systems framework (Markard et al., 2015), and, the multi-level perspective (MLP) on sociotechnical transitions (Geels, 2002, Geels and Schot, 2007).

Mindful of its ability to look at sustainability transitions by adopting a systemic perspective, which is "particularly appropriate for complex problems of unsustainability" (Whitmarsh, 2012: 483), we decided to focus our attention on the MLP framework and use it to advance theory in the field of smart city development. First conceptualized by Rip and Kemp (1998) and subsequently developed by Geels and other transition management researchers, the MLP is a theoretical framework which attempts to explain how long-term sociotechnical transitions occur at the level of societal functions. The MLP describes system transitions as non-linear processes which result from interactions between three analytical levels: “the niche-level that accounts for the emergence of new innovations, the sociotechnical regime level that accounts for the stability of existing systems, and the sociotechnical landscape that accounts for exogenous macro-developments” (Geels, 2007: 642). Central to this theory is the legacy of science, technology, and society studies (Shove and Walker, 2010), and their refuse for a technological deterministic interpretation of innovation processes (Bijker, 2010). MLP theories go beyond the simple acknowledgment of the critical role that technological advancement has in the shaping of the innovation trajectories of societal functions, recognizing that the adoption of technology and its capability to generate progress are socially shaped (Bijker and Law, 1992, Williams and Edge, 1996). The innovation capacity of any technology always depends upon human agency and the organizational, institutional, political, cultural, technological, environmental, and socio-economic dynamics of an existing order (Boudreau and Robey, 2005, Pesch, 2015, Rauschmayer et al., 2015).

We used the MLP as an underlying framework for developing a middle-range theory of sustainable smart city transitions (see Figure 1). The proposed theory builds upon the empirical observations surfacing from an inductive theory-building exercise. Evidence has been sourced from available empirical studies reporting on the sociotechnical developments which enable smart city transitions. After being collected, this evidence has then been examined in the framework of both the MLP, which has been deployed as an analytical model, and widely accepted theoretical assertions incorporated in knowledge fields which are relevant to the study of smart cities. Bridges have been formed between theorizing in smart city research and some of the “foundational assumptions” (Geels, 2010: 496) underpinning transition management and system innovation studies, human geography, spatial planning, and critical urban scholarship.

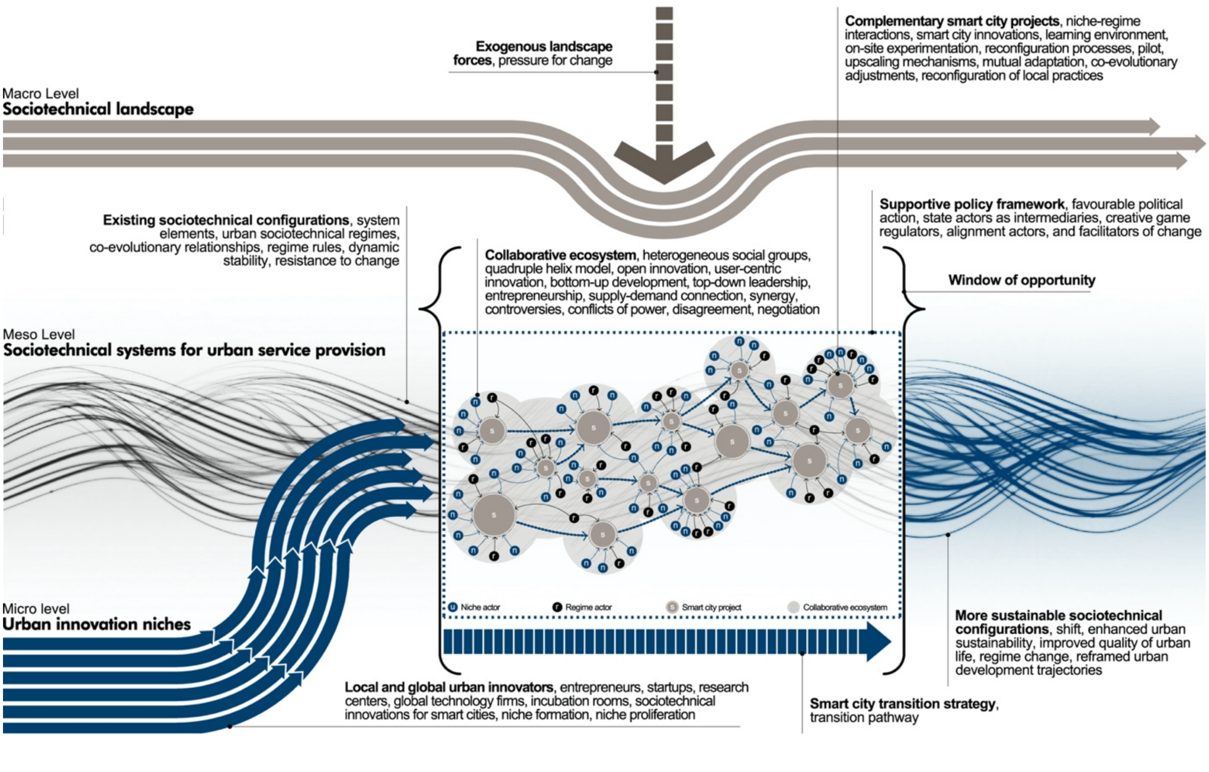

Figure 1. A middle-range theory of sustainable smart city transitions. Adapted from Geels (2011) and Geels et al. (2017b)

Our interdisciplinary theoretical formulation focuses on the "process of emergence" (Batty, 2017: 395) of smart city transitions and provides a general conceptual scheme. This scheme details our evidence-based interpretation of how smart city transitions should be conceptualized and enacted in order to overcome the oversimplification fallacy resulting from corporate discourses on smart urbanism. This brings new theoretical insight which helps move beyond the "purely deconstructive critique of the dangers of techno-utopianism" (Bina et al., 2020: 12) where the smart city discourse is stuck.

However, it is important to note that the purpose of our middle-range theory is not to discover nomothetic scientific laws which can be generalized to the entire target population (Welch et al., 2011), but rather to guide empirical inquiry in smart city research, by offering a broad and realistic understanding of smart city transitions. The proposed theoretical perspective combines different smart-city-related concepts in a model which attempts to expose what "patterns, regularities and stylized mechanisms" (Geels, 2007: 631) surface in sustainable smart city transitions. Our objective is to give smart city research more robust scientific foundations, by building on the science of cities, system innovation, and transition management, and to generate theoretical propositions upon which subsequent large-scale empirical testing can be conducted (Corner and Ho, 2010). With the proposed middle-range theory, different empirical settings can be investigated by "using the same analytical elements" (Fararo, 2001: 15660). A shared framework can facilitate the cross-case analysis and synthesis of the systematic research efforts which are progressively contributing to shading light on the assemblage of sustainable smart city transitions, helping to address a challenge that decision makers involved in smart city transition arenas do struggle with.

To facilitate cross-case analysis and synthesis, our theoretical contribution also addresses what Pinder and Moore (1980: 9) would describe as "the loss of parsimony". Back in the 80s, while analysing the main scientific trends in organizational behaviour studies, Pinder and Moore noted a growing attitude of researchers to make use of multivariate research methods. However, this trend was growing together with a lack of standardization in defining the parameters and variables used in their analyses. As a consequence, organizational behaviour studies started being "full of fuzzy concepts and of similar but not identical definitions of terms, resulting in an inability to achieve parsimony" (Pinder and Moore, 1980: 9). Smart city research is affected by the same absence of semantic clarity (De Jong et al., 2015, Mora et al., 2017), and the proposed middle-range theory makes explicit efforts to demarcate smart-city-related concepts and clearly define their meaning and interrelation.

3.1. The landscape-system-niche connection in smart city transitions

Smart city transitions occur by following the overall theoretical logic underpinning sustainability transitions (see Geels, 2014, Geels et al., 2017b, Raven et al., 2012), which is best placed to explore the causal agency and causal development mechanisms laying the foundations of these digital urban transformations.

First, smart city transitions typically unfold over a considerable timespan, but the speed at which they take place largely depends upon many contextual factors, such as the political scenario, level of coordination among stakeholders, existing legal and regulatory frameworks, spatial configuration of the transition (for example, neighborhood, city, regional or national level), geographical factors, and the stability of the smart city technology under consideration, whose development and practical application can be largely unrealized. For example, "short take-over times of less than 25 years are […] not common for major infrastructural systems" (Sovacool, 2016: 206) and the longstanding transition towards real-time, data-driven management of urban systems confirm this assertion. Boosted by advancements in big data analytics and Internet of Things (IoT) technologies, this complex transformation can introduce the means for better understanding how urban sociotechnical systems function and improve urban planning practice and policy making (Batty, 2013b). City governments started realizing the growing importance of harnessing the power of urban analytics in the 1990s, the period in which this transition process started (Martin et al., 2019). But after three decades, this smart city transition is still in progress, because sensing the city through urban analytic techniques has yet to become a common practice in the public sector (Batty, 2012).

Second, smart city transitions clearly result from co-evolutionary and mutually reinforcing endogenous and exogenous developments (Barba-Sánchez et al., 2019, Simmons et al., 2018, Trencher, 2019), which take place at the three levels of aggregation identified in the MLP framework (see Geels et al., 2017b): sociotechnical landscape (macro-level); sociotechnical systems for urban service provision (meso-level); urban innovation niches (micro-level). Although we know that smart city transitions strongly depend upon local arrangements, the general dynamic is that, when these endogenous and exogenous developments combine, new configurations of urban sociotechnical systems surface. These new sociotechnical settings largely replace the existing ones and reframe the functioning and developmental trajectory of the urban environment, shifting towards more sustainable paths.

This interpretation of smart city transitions builds on the organismic conceptualization of urban environments, which results from the introduction of complexity theories, sociotechnical systems thinking, and evolutionary economics in the context of spatial planning (Mehmood, 2010, Söderström et al., 2014). The overarching vision of this organic understanding is that urban environments can be envisioned as a multitude of open sociotechnical systems (Batty, 2005, 2009), which are interrelated and whose organization is governed by routines, flexible adaptivity, and the combination of bottom-up and top-down stimuli (Bertolini, 2007). The functioning of urban sociotechnical systems strongly depends upon the complex interdependencies linking their elements (Baxter and Sommerville, 2011, Carayon, 2006). System elements include citizens, organizations, culture, policy and regulations, technology, markets, and physical urban infrastructure components. As highlighted in studies on transition management (Geels et al., 2017b) and human geography (Haarstad and Wanvik, 2017), the elements composing a sociotechnical system are connected by coevolutionary relationships and their interplay depends upon existing sociotechnical arrangements. These arrangements make the system dynamically stable but also resistant to change. Therefore, when new technologies are introduced, they "must compete with technologies that benefit from well-developed systems around them" (Geels, 2012: 473) and which have gained precise user understanding.

The arrangement of urban sociotechnical systems and their development trajectories are regulated by urban sociotechnical regimes, large networks of heterogeneous social groups who legitimate the prevailing logic, routines, and path dependency regulating urban technological change (Haarstad and Wanvik, 2017, Nciri and Levenda, 2019). Regime actors are connected through "strong social, institutional, organizational, and cognitive relationships" (Raven et al., 2012: 70) and their behavior depends upon a shared set of rules which create lock-in mechanisms. Examples of regime rules include mutual perceptions and expectations, shared values and beliefs, preferences on institutional arrangements, policy priorities, cognitive routines, and consumption patterns (Geels, 2011, Geels and Schot, 2007). The stability of urban sociotechnical systems and their capability to fulfill societal needs result from the alignment between the rules agreed by regime actors and the exogenous contextual developments embedded in the landscape level. The presence of misalignment requires changing the sociotechnical configuration of both urban systems and the regimes which regulate their functioning. This pressure for change weakens incumbent sociotechnical configurations and generates a window of opportunity for niche actors who are willing to engage in digital urban innovation dynamics (Geels et al., 2017b).

Exogenous forces, which develop in the landscape level, influence existing urban sociotechnical systems and their capability to meet the societal needs of urban communities. This external context stimulate change and trigger the growth of smart city innovations (see Hashem et al., 2016, Kim et al., 2017, Lu et al., 2019), but its evolution is beyond the direct control of regime and niche actors who cannot influence the configuration of the landscape in the short term (Geels, 2012, Schot and Kanger, 2018). The exogenous development processes embedded in the sociotechnical landscape comprises "slow-changing trends (e.g., demographics, ideology, spatial structures, geopolitics) and shocks (e.g., wars, economic crises, major accidents, political upheavals)" (Geels et al., 2017a: 465). These macro-level developments generate forces (Schot and Kanger, 2018) which put existing urban sociotechnical systems and regimes under pressure (Hodson and Marvin, 2010). These landscape forces unfold autonomously on urban sociotechnical systems and regimes (Smith et al., 2010), which are required to undergo reconfiguration processes in order to continue to serve societal needs while responding to the pressure for change (Geels and Schot, 2007).

Smart city transitions are triggered by two major exogenous landscape-type forces (Angelidou, 2015, Deakin and Reid, 2018), which are exerting pressure on existing urban sociotechnical systems and regimes. On the one hand, we have the pressure generated by the current state of urban environments and "the challenge of the sustainable city" (Hens, 2010: 875). The severe societal challenges facing urban spaces require the wide-ranging reform of urban development models. Common challenges to most urban areas include the following: either rapid urbanization or notable population loss; inequalities, segregation, and urban poverty; hunger, malnutrition, and food security; climate change and environmental degradation; growing budget deficits; air pollution; lack of public trust in government and political institutions; and population aging. Due to these challenges, which tend to coexist in urban environments and create synergetic negative effects, the quality of urban life is falling, and urban spaces are urgently required to undertake the deep-structural changes which are needed to make them evolve into more sustainable entities. Urban sociotechnical regimes are asked to proactively implement this long-term transformative vision. However, the implementation needs to be accelerated. Widespread agreement has been expressed by sustainable development actors on the inefficiency of the global response, which is not yet sufficiently transformative. The general vision is that grand challenges should be addressed more quickly (United Nations, 2019).

On the other hand, we have the widespread diffusion of digital devices, systems and applications, whose faster-than-ever progress has outpaced all other industry sectors (Nagy et al., 2013) and created a rapidly expanding network society (Castells, 1996). Emerging technologies and technological trends (such as high-speed Internet, wireless technologies, cheaper personal devices and sensor networks, the miniaturization of computing technology) have triggered a new technological revolution, which has radically changed human-to-human and human-to-computer interactions, as well as the way in which people behave, work, think, and engage with the physical environment (Mitchell, 1995, 2003). Modern digital technologies have changed the relationship between society and technology (Brey, 2018) and they are underpinning innovation in the private sector and across a broad range of markets, but they have also long been used to modernize the core functioning elements of urban systems. The strong transformative potential of digital technologies is putting pressure on urban sociotechnical regimes, who are struggling to establish how and to what extent the opportunities offered by the smart city technology market can be fully harnessed without incurring in unintended impacts.

The combination of global urban sustainability challenges and the strong transformative potential of digital technologies has opened up a window of opportunity which a growing number of urban environments across the world are experimenting with (Neirotti et al., 2014): unleashing the innovation potential of smart city technologies to satisfy unfulfilled urban sustainability needs, accelerate sustainable transformations, and improve the quality of urban life. Embedded in this window of opportunity is the vision of a digitally augmented urban sustainability (Graham and Marvin, 1996, Martin et al., 2019).

Local and global urban innovators (such as entrepreneurs, startups, research centers, and global technology firms) willing to support smart city transitions have the possibility to take advantage of this window of opportunity. They can emerge and influence the development of existing regimes, by bringing a variety of sociotechnical innovations for smart cities into urban environments. The adoption such technologies can help address the sustainability issues affecting urban sociotechnical systems, reinstate the necessary equilibrium, and trigger regime change (Smith et al., 2010). Examples of smart city innovations include new smart city technologies (Zanella et al., 2014), business models for smart cities (Timeus et al., 2020), new market and institutional arrangements (Vallance et al., 2020), new technological acceptance models (Sepasgozar et al., 2019), and design principles for smart city development (Mora et al., 2019b).

Powered by entrepreneurial spirit and interest in contributing to the shift to more sustainable urban futures, urban innovators organize in what transition management studies call niches (see Schot and Kanger, 2018). In the framework of smart city transitions, we define niches as spaces in which urban innovators develop sociotechnical innovations for smart cities. Innovation niches act as ‘incubation rooms’ (Geels, 2004), in which promising ideas are identified and then transformed into viable smart city innovations. This path of translating ideas into smart city innovations is typically managed by means of experimental journeys, which include research, design, and testing activities (Van Den Buuse and Kolk, 2019, Van Winden and Van Den Buuse, 2017).

The process of niche formation and proliferation creates a selection environment for smart city innovations. However, the ability of such innovations to support smart city transitions lies in a mutual adaptation process. This critical process starts when urban innovation niches and their smart city innovations are brought into the transition arena, where they meet the real life of urban environments and the diversity of their sociotechnical arrangements. “Technological developments are always performed locally” (Rip and Kemp, 1998: 353). Therefore, niche actors are required to form hybrid alliances with regime actors and collaborate in implementing smart city projects (Komninos et al., 2013). Smart city projects are cross-sector projects which aim to create the conditions needed for smart city innovations and the existing sociotechnical configuration of local practices to mutually adapt. Smart city projects set in motion a dynamic learning environment, on-site experimentation with smart city innovations, institutional reconfiguration processes, and other complementary changes which support the wider adoption of smart city technologies and make it possible to solve issues of technical and social adaptation (Cohen et al., 2016, Cook et al., 2019).

Given the evolutionary character of sociotechnical change, the outcome of a smart city project is difficult to define in advance and it can fail to meet the expectations. In addition, these projects typically start with a pilot phase which is instrumental in generating scalable solutions. However, the search for optimal upscaling mechanisms is still in progress (Van Winden and Van Den Buuse, 2017). This knowledge gap represents a major problem in smart city transitions, because many smart city projects “remain small and experimental, and fade out after a (subsidized) demonstration phase; as a consequence, the impact of solutions developed in these pilot projects on urban development often remains limited” (Van Winden and Van Den Buuse, 2017: 52).

During smart city transitions, complementary smart city projects are launched, which transform the urban environment in a vibrant construction site (Caird and Hallett, 2019). Their implementation generates patterns of coevolution within an expanding collaborative ecosystem which puts open innovation principles, user-centric and bottom-up development, and entrepreneurship at the service of sustainable urban development (Cohen et al., 2016, Vallance et al., 2020). In this collaborative environment, niche and regime actors join forces in order to frame new sociotechnical configurations that work. This activity relies on the innovation capacity generated by the industry-government-research-public relationships of the quadruple-helix collaborative model of stakeholder engagement. This collaborative model ensures that supply is articulated in interaction with demand, and it also helps to tap into the knowledge, creativity, entrepreneurial skills of the public (Mora and Deakin, 2019). The collaboration among heterogeneous actors generates synergies, but antagonistic interactions may also surface which require negotiations (Whitmarsh, 2012). Different perceptions and interests can lead to tension among social groups, controversies, and conflicts of power. In addition, because smart cities represent an ambiguous concept, disagreement can easily surface about the direction of the reconfiguration process and approach to implementation, the selection of particular smart city innovations, and the policy instruments to deploy during the transition (Khan et al., 2020, Zuzul, 2019).

Experiments with smart city technologies in urban sociotechnical systems for energy and transports have shown that the cumulative effects of smart city projects stimulate change at the regime level (Haarstad and Wathne, 2019, Parks, 2019, Whitmarsh, 2012). But this transformation process is neither immediate nor linear (Geels, 2002, 2005, Smith et al., 2010). Reconfiguration processes can bring about opportunities for radical change (Whitmarsh, 2012), but they occur “incrementally, with small adjustments accumulating into stable trajectories” (Geels, 2011), and involve multi-dimensional changes which combine bottom-up and top-down developments (Mora et al., 2019b). The case study analysis presented by Chang et al. (2020) provides additional supporting evidence which shows the potential for regime change of smart city projects. By focusing on Taipei, the capital city of Taiwan, the authors conclude that the smart city transition process has facilitated the transition to “a more autonomous urban regime, while also opening up a new arena of contestation” and smart city projects “have the political capacity to reshape power dynamics and regime formation through reorganizing actors and interest groups, reconfiguring government institutions, redistributing resources and promoting governing legitimacy” (Chang et al., 2020: 17).

During the smart city transition process, shifts in technological systems fulfilling urban service provision take place. However, the transformation also implies co-evolutionary adjustments of non-technological assets (Elsner et al., 2019). Stable configurations are searched and shaped during smart city projects, by experimenting with new sociotechnical structural arrangements. With the proliferation of smart city projects, new smart technologies, digital services, business models, market arrangements, and organizations progressively emerge in the configuration of sociotechnical urban systems, and these new elements complement or substitute the existing ones. Technological structures and physical urban infrastructure components are modified fundamentally, while urban socio-economic and environmental frame conditions, institutional settings, interorganizational collaborative arrangements, policy directions and political settings, knowledge production mechanisms, and the cultural perceptions, preferences, and behavior of urban communities (Mora and Deakin, 2019).

The main transition dynamics occur when micro and meso levels engage. The interactions between niche and regime actors shape a transition pathway which builds on a multitude of smart city projects. The success of a smart city transition depend upon the functioning of the collaborative environment in which such projects are developed. However, it is also important to highlight that this transformation is also a “highly political process” (Elsner et al., 2019: 648), strongly influenced by public sector decision-making (Britton, 2019). Governmental bodies play a key role in the shaping of smart city transitions and their main task is to drive the dynamics of sociotechnical change into a desirable direction. By acting as intermediaries, “creative game regulators, alignment actors, and facilitators of change” (Rip and Kemp, 1998), state actors are required to: encourage strategic interactions between different social groups and their communication; create room for experimentation; make sure that the process remains open, inclusive and cohesive; support interested parties who might not be heard; break silos; facilitate interactive learning processes related to urban issues, needs, and possibilities; guide technology developers in their decisions; orient search and selection processes of smart city innovations; and, keep the transition process oriented towards a fully sustainable path. This approach to implementation combines top-down leadership and bottom-up development and has been detailed in a number of case study analyses investigating smart city transitions in large European, American and Asian cities (see Lee et al., 2014, Mora and Deakin, 2019).

As highlighted in the sustainability transition studies already referred to, accelerating regime transition requires political action to readjust public policies (Goyal and Howlett, 2020) and arbitrate when competing propositions, resistance, and powers struggles hindering the transformation emerge (Wironen and Erickson, 2020). As a result, formal institutional frameworks are modified by setting and enacting new laws, guiding principles, norms, and procedures which regulate power relations in niche-regime interactions (Dolata, 2009, López-García et al., 2019) and facilitate the development of multi-actor networks, protecting and deepening the reach of smart city transitions (Brown et al., 2013).

4. Objective and contribution of this special issue

Organized in a general scheme, the proposed middle-range theory extracts the conceptualization of smart city transitions from the oversimplified vision of the corporate sector. In addition, it helps to better understand the complexity of the transition process and attempts to explain how the transformation unfolds when approached in a sustainable manner. However, our empirical observations also leave many knowledge gaps which are caused by the underdeveloped empirical context in which smart city development research is placed. Despite almost three decades of research, we know very little about the dynamics of smart city transitions, how they adapt to different geographical contexts, and how to ensure that the transformation process maximizes societal benefits without incurring in negative externalities. If we want smart city transitions to express their potential for enhancing the sustainability of urban environments and improving the quality of urban life, significant research efforts are still required.

The following are a few examples of the many relevant research questions which have yet to be answered:

- What key performance indicators and metrics should be assembled to evaluate smart city transitions (Deakin and Reid, 2018)?
- What are the cultural, financial, and institutional barriers to smart city transitions and what should be done in order to overcome the limitations they generate (Rana et al., 2019)?
- What business models should be adopted in order for the transition process to be inclusive, safe and resilient (Walravens, 2015)?
- What are the key activities and phases to be considered when designing and implementing strategies for enabling smart city transition processes (Mora and Bolici, 2015)?
- How can privacy concerns and controversy arising from the development of smart city transitions be detected and managed (Van Zoonen, 2016)?
- How can justice and ethics be integrated in the smart city transitions process (Jenkins et al., 2018)?
- How should niche and regime intermediation be organized (Kivimaa et al., 2017)?

The 14 articles presented in this Special Issue (see Table 1) help overcome some of the theoretical and practical shortcomings of the smart city research conducted so far, and they contribute to expand the middle range-theory of sustainable smart city transitions that we advance. The Special Issue proposes theoretical and empirical papers of an interdisciplinary nature, which offer new insights into how smart city transitions can help meet the sustainability challenges that urban environments are facing. These insights are expected to advise urban development actors as to how smart city transitions can be assembled as sustainable developments. Despite focusing on different dimensions of change and analytical elements, all the papers share the same desire to guide the smart city transition process towards the construction of environmentally friendly, resource efficient, safe, inclusive, and resilient urban environments, which not only sustain an economic growth based on the principles of sustainability and inclusive prosperity, but that also provide equal access for all to public goods and high-quality urban services.

[Insert Table 1 here]

But before briefly introducing each article, we would like to gratefully acknowledge the contribution of everyone who has helped us develop this Special Issue, which is the outcome of a multidisciplinary, international, and highly collaborative research community. This initiative has brought together 48 authors, who represent 28 research centers, 16 countries, and 6 continents (Africa, Asia, Australia, Europe, North America, and South America). Not to mention the many smart city researchers, whose work has been pivotal during the peer-review process, as well as Richard Hanley, Editor-in-Chief of the Journal of Urban Technology, for providing us with the opportunity to develop this initiative and invaluable constant support. We would like to thank everyone involved for their efforts and commitment.

In the first article of the Special Issue, Wu et al. (2020) set the scene by presenting the findings of a bibliometric analysis which explores the research area that has emerged from the interconnection between smart city and urban sustainability studies. By combining a selection of citation-based and content-analysis techniques, this article offers an overview of how this emerging knowledge field is structured. The most influential journals, articles, and knowledge producers are mapped and discussed, along with both dominant and emerging thematic research areas.

Aurigi and Odendaal (2020) propose a theoretical contribution which introduces two new concepts: “Smart in the Box” and “Smart in the City”. The former is used to describe the fundamental logic underpinning the unsustainable industry-led approach to smart city development. In this vision smart cities appear as a set of ready-to-use technological tools which are developed outside urban environments and subsequently introduced with a top down, centralized approach that does not take into account existing sociotechnical arrangements. Positioning themselves against the rationale of this one-size-fits-all mentality, the authors invite to conceptualize “smart in the city”, stressing the importance of conceiving smart city transitions as context-sensitive and place-based transformations in which technology and existing sociotechnical arrangements mutually adapt.

The investigation into how smart city transition pathways should be conceptualized continues with Noori et al. (2020), who design a societal variant of an input-output model. This conceptual model attempts to provide urban development actors with a comprehensive understanding of how smart city transition arenas are organized. The model is informed by a systemic review of the smart city literature, from which the authors source some of the key elements of smart city transition processes. These elements have then been used to assemble the proposed input-output model for smart city development, in which existing interdependencies are delineated. The article concludes with an illustrative case study analysis. The authors examine the smart city transition of Dubai in the framework of their conceptual model in order to show its functioning and the potential benefits that its deployment may generate.

With Komninos et al. (2020), the attention moves from the conceptualization of smart city transitions to their design and implementation. This article outlines a set of recommendations which are built upon the lessons learned from a group of European cities and their smart city transition strategies: Sofia, the capital and largest city of Bulgaria; Granada, in the autonomous community of Andalusia, Spain; and the Greek city of Kavala. A key point that emerges from the cross-case analysis is the interdependency of sociotechnical systems for urban service provision. As the authors note, the three cities have implemented smart city transitions which unfold vertically, by means of a the transformation process which is restricted to a single or few urban sociotechnical systems and their attending regimes. Despite a different focus, the article notes that the dynamics of change are nevertheless similar because urban systems share multiple elements, such as infrastructure components, markets for digital services, the cultural context, and the regulatory setting which determines innovation funding mechanisms. According to the authors, this high level of interdependency indicates that smart city transition strategies may be more efficient when the intervention logic is horizontal and holistic rather than vertical. This observation suggests there may be an interesting (and under investigated) connection between the economy of scale theory and smart city transitions.

Du et al. (2020) and Yigitcanlar et al. (2020) propose two different strategic planning tools which show the potential which exists for an evidence-informed design of smart city transition strategies. Du et al. (2020) design a new methodological technique for detecting spatial inequalities in the basic service provision of metropolitan cities, while Yigitcanlar et al. (2020) show how systemic geo-Twitter analytics can be deployed to look into how smart city concepts and technologies are perceived and utilized in urban environments. The effectiveness of the proposed methodologies is proved in the empirical settings of New York City and a group of Australian cities, respectively.

Designing and implementing smart city transition strategies also requires a good understanding of what risk may hinder the successful implementation of smart city projects and the search for mutually adapting configurations able to connect new smart city innovations to existing local practices. Research in this knowledge area has remained limited, especially in developing countries, and Gupta and Hall (2020) help improve our current understanding with an analysis of Kakinada and Kanpur. By examining the smart city projects implemented in these two Indian cities, the authors identify a set of critical risks and reveal their the causal relationships. By reporting on the findings of this case study analysis, the authors suggest risk mitigation strategies for smart city transitions should plan measure that treat risks in a systemic matter rather than attempting to manage them in isolation from one another.

Drawing on empirical evidence stemming from the analysis of a leading Dutch telecommunications firm, Van Den Buuse et al. (2020) offer insight into how firms can move from experimentation to upscaling in the framework of smart city transitions. The study confirms that an ambidextrous approach, in which both exploration and exploitation are combined, may help companies to find the balance between public and private interests and facilitate the adoption of smart city technologies in urban environment. Building on the findings of their study, Van Den Buuse and colleagues identify several recommendations whose objective is to advice local governments on how to manage the scale up phase of smart city technologies and address urban sustainability challenges more effectively.

Anjomshoaa et al. (2020) open the second section of the Special Issue. The emphasis of the first group of articles mainly centers on the overall conceptualization, planning, and implementation of smart city transition strategies, whereas the last six contributions are more narrowly focused. The attention moves from the broader strategy to sector-specific smart city innovations and the contribution they make to smart city transitions related to urban mobility and urban governance systems. For example, Anjomshoaa et al. (2020) investigate the effect of street network topology on the quality of data captured by means of large-scale drive-by sensing approaches. Enabling drive-by sensing in urban environments has the potential to reduce sensor deployment and maintenance costs, while improving the monitoring of environmental phenomena in urban environments, such as air quality. Drive-by sensing requires the deployment of mobile sensors on urban vehicles that routinely navigate through city streets. Building on a number of drive-by sensing experiments conducted in North America and Europe, Anjomshoaa and colleagues advance new methods and indicators which can facilitate the management of drive-by sensing scenarios in urban environments.

With a study which explores the joint impact of vehicles electrification and ridesourcing on urban travel, Tu et al. (2020) continue the investigation into the relationship between smart city development and urban mobility. By applying a big-data-driven framework, the authors analyze three types of urban mobility patterns in the city of Beijing (household, ridesource, and taxis) and compare their electrification potential. Their analysis demonstrates that: (1) the three mobility patterns are similar when observing a single trip, but they differ significantly when the total daily vehicle travel is taken into account; (2) the potential acceptance of electric vehicles decreases significantly from household to ridesourcing and taxi vehicle usage.

Martelli et al. (2020) contribute to the debate around privacy control when using mobility sharing applications. Transportation and location data can signal important aspects concerning the habits of individuals, their preferences, and behaviors. The novelty of this study lies in the effort made to quantify the effects of privacy control on ride-sharing applications, capturing the trade-off between data privacy and data utility in the context of home-work carpooling. The study reveals that data location privacy impacts both efficiency and quality of service. These findings open important questions on where the best trade-off lies between the individual privacy right of citizens and the societal need to increase urban transportation efficiency.

Nochta et al. (2020) further highlights that a shift from a purely technical understanding to a sociotechnical perspective is needed to support sustainable smart city transitions. However, it is important to understand how this change of mentality affects the conceptualization, design, and implementation of smart city projects whose aim is to develop new technological tools. The authors examine the City-scale Digital Twin (CDT) prototype of the Cambridge city region, in the United Kingdom. CDTs are urban analytics tools and, by reflecting upon the modeling framework used for the Cambridge CDT system, Nochta and colleagues distil the key findings into recommendations on how social and technical insights can be combined in smart city projects.

Smart city technologies for urban governance systems are also the center of attention in the last two paper. More specifically, focusing on issues of usability and data literacy, Young et al. (2020) report on the user-centered redesign process of the Dublin Dashboard, whereas Smith and Martín (2020) examine the digital platforms for urban democracy introduced in Madrid and Barcelona in in 2015 and 2016, respectively. The findings presented in each article contribute to demonstrating that co-design practices in a smart city context are indispensable for creating the conditions necessary for smart city technologies and existing local practices to mutually adapt.

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