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Understanding Smart Cities: Innovation ecosystems, technological advancements, and societal challenges

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ABSTRACT

Smart Cities initiatives are spreading all around the globe at a phenomenal pace. Their bold ambition is to increase the competitiveness of local communities through innovation while increasing the quality of life for its citizens through better public services and a cleaner environment. Prior research has shown contrasting views and a multitude of dimensions and approaches to look at this phenomenon. In spite of the fact that this can stimulate the debate, it lacks a systematic assessment and an integrative view. The papers in the special issue on "Understanding Smart Cities: Innovation Ecosystems, Technological Advancements, and Societal Challenges" take stock of past work and provide new insights through the lenses of a hybrid framework. Moving from these premises, we offer an overview of the topic by featuring possible linkages and thematic clusters. Then, we sketch a novel research agenda for scholars, practitioners, and policy makers who wish to engage in – and build – a critical, constructive, and conducive discourse on Smart Cities.

1. Introduction and motivation

There are hundreds of smart city projects currently being developed around the world (Lee et al., 2014). Smart Cities initiatives aim to "provide more efficient services to citizens, to monitor and optimize existing infrastructure, to increase collaboration amongst different economic actors and to encourage innovative business models in both private and public sectors" (Marsal-Llacuna et al., 2015, p. 618). Ultimately, smart cities strive to increase the competitiveness of local communities through innovation while increasing the quality of life for its citizens through better public services and a cleaner environment.

In order to achieve these goals, smart cities rely on state-of-the-art information technology (e.g., fiber optic networks, sensors and connected devices, open data analytics, internet of things, ICT-enabled participatory planning frameworks) on the one hand (Albino et al., 2015; Stratigea et al., 2015), and on human capital (e.g., research universities, knowledge-intensive companies and public institutions) on the other hand (Ahvenniemi et al., 2017; Neirotti et al., 2014). Angelidou (2014) calls the former "hard" smart cities strategies (smart buildings, smart energy grids, smart water management, smart mobility) and the latter "soft" strategies (developing human and social capital through education, culture, social inclusion, social innovation). It is widely assumed that the digital infrastructure of modern cities offers a unique opportunity to facilitate entrepreneurship, creativity, and innovation in order to drive local economic growth (Kraus et al., 2015; Grimaldi and Fernandez, 2015). The city of London, for instance, has based its smart city initiative on four dimensions: a) technology innovation; b) open data and transparency; c) collaboration and engagement; d) efficiency and resource management (Angelidou, 2015). These dimensions echo Lee and co-authors' (2014) six enablers of smart city development: urban openness, service innovation, partnership formation, urban proactiveness, infrastructure integration, and smart city governance. Chourabi et al. (2012) propose an "integrative framework" involving the dimensions of organization, policy, and technology as the pillars of smart city initiatives, surrounded by secondary factors such as governance, people/communities, economy, infrastructure, and natural environment.

Alternative frameworks highlight the "transboundary" nature of smart city projects. Thus Angelidou (2014) suggests the necessity to go beyond the "hard versus soft" infrastructure dichotomy and to also consider the national versus local implications for smart city projects; the new (green field) versus the existing (brownfields) approaches to urban development; and the economic versus geographic approaches. Similarly, Ramaswami and co-authors (2016) suggest thinking about the local infrastructure provision (the smart management of energy, buildings, public spaces, waste and sanitation, food supply, water

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supply and transportation) as subject to a larger flow of national and global actors and institutions. The performance of these initiatives must be measured in terms of their environmental, economic, and social benefits (Ahvenniemi et al., 2017). These initiatives can also be studied from a strategic perspective, as they can spark the emergence of new value chains in the firms and stakeholders involved in designing and executing smart city projects (Paroutis et al., 2014).

According to the neo-evolutionary perspective of the Triple Helix framework, smart city projects represent a unique innovation platform for companies, government agencies, and researchers (Leydesdorff and Deakin, 2011). In this perspective, smart cities are perceived above all as "Intelligent Communities", collaborative ecosystems that facilitate innovation, by creating linkages among citizens, government, businesses, and educational institutions. These innovative clusters foster the development of high added value activities of the "knowledge economy."

To capture most of these elements, Bill Hutchison (Hutchison et al., 2011) created a 5-level pyramid framework called "Intelligent Community Open Architecture – i-COA®." The first two levels correspond to the "hard" smart city strategies (places and infrastructure). The top three levels (collaboration ecosystems, applications, and life) correspond to "soft" strategies. This framework has the merits of being synthetic, easy to visualize, and suggests that the ultimate goal of smart cities is not merely to connect hardware and infrastructure, but to create collaborative environments where innovation and quality of life can thrive.

All of these models are indebted to Giffinger et al.'s (2007) seminal classification of smart city characteristics around six key dimensions: quality of life (Smart Living), competitiveness (Smart Economy), social and human capital (Smart People), public and social services and citizen participation (Smart Governance), transport and communication infrastructure (Smart Mobility), and natural resources (Smart Environment). For the purposes of this discussion, therefore, we propose to merge Hutchison's and Giffinger's frameworks as a background to understand how smart cities may foster collaboration ecosystems that may improve both the standards of living and the competitiveness of urban spaces (Fig. 1).

Urban strategist Boyd Cohen (2013) developed a "Smart City Wheel" that suggests how to measure the six dimensions of Giffinger's model. At the risk of oversimplifying the problem, this model has the merit of reducing the metrics of each dimension to three indicators only. It is a good synthesis of an introductory discussion about smart cities limits and possibilities. However, it lacks the structural perspective of Hutchinson's i-COA® framework to create a hierarchy of smart city elements. Indeed, according to Hutchinson's model, every smart city project must start with the physical infrastructure (Smart Environment and Smart Mobility). This is the basis for creating innovation ecosystems based on human and social capital (Smart People and Smart Economy). Such de-centralized initiatives require articulation and coordination by public entities or public-private partnerships (Smart Governance). The *raison d'être* for these governance structures is to provide better quality of life solutions to smart city citizens (Smart Living). Thus, by combining Giffinger's classic categories and organizing them according to Hutchinson's pyramid, we suggest a visual diagram of how to design, implement and measure smart city programs (see Fig. 1).

According to Dustdar et al. (2017), most definitions of smart cities are infrastructure-centric, focusing on installation and subsequent management of connected devices and analytics of data. Table 1 corroborates this perception. As seen above, few definitions emphasize the three dimensions simultaneously. The hybrid framework proposed here attempts to avoid this bias by emphasizing the role of infrastructure in smart city projects simply as a means to achieving more collaborative innovation ecosystems and ultimately leading to a higher quality of citizens' life. In the following session, we conduct a literature review based on these three elements of the proposed hybrid model.

2. The physical infrastructure of smart cities

According to certain estimates (Suzuki, 2017), 180,000 people migrate to cities across the globe every single day, which represents over 65 million new urban dwellers a year. The challenges created by this massive urban migration in terms of housing, electricity, heating, and schooling (not to mention job creation) are overwhelming. In order to develop intelligent solutions, a combination of smart networks (Internet of Data, Internet of Things, Internet of Services and Internet of People) can be used to minimize environmental impact while maximizing social well-being and promoting collaborative eco-systems (Ijaz et al., 2016).

The Internet of Data has been among us since the inception of the Arpanet project in the 1960s. However, the advent of widespread broadband communication infrastructure in offices and homes in the 21st century dramatically increased the velocity, volume, variety, veracity and value of data transfers (commonly called Big Data networks). These massive data streams are derived not just from human-created content (blogs, social networks, video conferencing, etc.), but also from machines exchanging data among themselves (Internet of Things). Coupled with sophisticated statistical algorithms to gather, visualize and analyze this flow, Big Data has created opportunities to

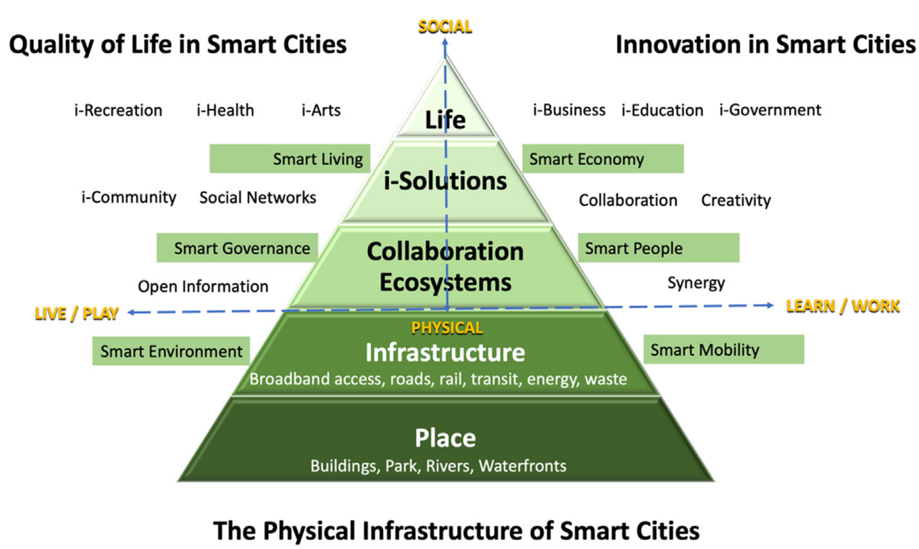

Fig. 1. An adaptation of Hutchison's i-COA® framework highlighting Giffinger's smart city elements.

Table 1
We summarize a number of smart cities definitions from the literature, classifying its primary focus in terms of the three components described above: physical infrastructure (PI), quality of life (QL), and innovation ecosystems (IE).

Definition of smart city	Authors	Focus
A city that monitors and integrates conditions of all of its critical infrastructure including roads, bridges, tunnels, rails, subways, airports, seaports, communications, water, power, even major buildings can better optimize its resources, plan its preventive maintenance activities, and monitor security aspects while maximizing services to its citizens	Hall (2000)	PI
A city well performing in a forward-looking way in economy, people governance, mobility, environment, and living built on the smart combination of endowments and activities of self-decisive, independent, and aware citizens	Giffinger et al. (2007)	PI/IE/QL
The use of smart computing technologies to make the critical infrastructure components and service of a city—which include city administration, education, health care, public safety, real estate, transportation, and utilities—more intelligent, interconnected, and efficient	Washburn et al. (2009)	PI
Instrumented, interconnected and intelligent. Instrumented refers to sources of near-real-time real-world data from both physical and virtual sensors. Interconnected means the integration of those data into an enterprise computing platform and the communication of such information among the various city services. Intelligent refers to the inclusion of complex analytics, modeling, optimization, and visualization in the operational business processes to make better operational decisions.	Harrison et al. (2010)	PI
Smart cities are those that are combining ICT and Web 2.0 technology with other organizational, design and planning efforts to de-materialize and speed up bureaucratic processes and help to identify new, innovative solutions to city management complexity, in order to improve sustainability and "liveability".	Toppeta (2010)	IE/QL
Systems of people interacting with and using flows of energy, materials, services and financing to catalyse sustainable economic development, resilience, and high quality of life		PI/IE/QL
A coherent urban development strategy developed and managed by city governments seeking to plan and align in the long term the management of the various city's infrastructural assets and municipal services with the sole objective of proving the quality of life for the citizens.	Dustdar et al. (2017)	PI/QL
Provide better services for citizens; provide a better life environment where smart policies, practices and technology are put to the service of citizens; achieve their sustainability and environmental goals in a more innovative way; Identify the need for smart infrastructure; facilitate innovation and growth; and build a dynamic and innovative economy ready for the challenges of tomorrow.	ISO (2018)	PI/IE/QL

learn in real-time about how to improve traffic, save energy, regulate public transit, reduce waste and pollution and improve safety in large urban centers across the world (Kitchin, 2014; Lim et al., 2018).

This Internet of Data in smart cities is increasingly dominated by the growing Internet of Things ecosystem. In the last two decades, there has been a dramatic acceleration of hardware performance at lower costs (based on Moore's Law) coupled with drastic miniaturization of components, leading to the ubiquity of smart objects. In 2003, there were an estimated 500 million connected devices worldwide or 0.08 object per person. This proportion increased to 1.84 in 2010 (12.5 billion connected devices to 6.8 billion humans) and reached 3.47 in 2015 (25 billion Internet of Things components to 7.2 billion humans). This ratio is expected to reach 6.58 by 2020 (Suzuki, 2017). The convergence of Big Data, Internet of Things and Artificial Intelligence promises to create better places (parks, buildings, homes) by providing smarter infrastructure (transportation, energy, waste management). These correspond to Giffinger's Smart Environment and Smart Mobility elements (Fig. 1). The following paragraphs discuss each of these domains.

2.1. Smart Environment

Smart Environment initiatives involve the use of technology to improve crucial aspects of city living such as waste disposal, food growth, pollution control, smart electric grids, housing quality, and facility management. This session presents a few state-of-the-art examples of how the Internet of Data and the Internet of Things can help reduce the ecological footprint of smart cities.

According to Perera et al. (2014), the widespread use of IoT sensors (such as Radio Frequency Identification chips, proximity detectors, pressure sensors, optical sensors) can drastically change the way we manage the smart city environment. City councils may optimize garbage collection, sorting and recycling by deploying low-cost smart sensors in garbage cans, trucks and recycling plants that share real-time data about the quantity and the quality of urban waste in each neighborhood. This intelligence may not only facilitate decision making in terms of logistics and urban strategy but can also inform educational campaigns to improve recycling behavior.

In agriculture, sensors can monitor plant growth under different conditions, pest control and soil conditions, allowing bio-scientists and microbiologists to develop customized treatments to minimize the use of toxic pesticides and fertilizers. Pollution control is another major field of IoT application. Sensors can help detect and prevent wildfires, automatically alert against the level of microparticles and other air pollutants, improve prediction, visualization and simulation of city pollution. Wireless Sensor Networks can be deployed in buses, bus stations, metro wagons and private vehicles to monitor emissions while also learning about how to make them more energy efficient (Jamil et al., 2015).

Concerning energy distribution opportunities, the so-called "smart grid" architecture allows the deployment of systems that optimize the use of renewable energy sources based on real-time statistics about usage. These grids are capable of self-healing (or at least self-diagnosis) in severe weather conditions, reducing outages and improving the quality of service. Thanks to connected solar panels, connected meters, virtual power plants and microgrids, consumers can become net-positive energy providers to the grid ("prosumers"). This can be done by storing extra capacity in connected battery packs that can redistribute energy in peak hours (Koutitas, 2018).

Finally, better infrastructure can be created through the development of smart homes, smart buildings, and connected facility management initiatives (Al-Hader and Rodzi, 2009). In the consumer space, Artificial Intelligence algorithms can learn about the habits of home dwellers and optimize heating through connected thermostats; security can be increased through connected cameras, the ubiquity of intelligent fridges can help individuals, supermarkets and food producers to better regulate their stocks, possibly reducing food waste. Concerning business environments, advanced facility management applications are being developed to monitor and improve electricity, communication, water, sewer, gas, and air conditioning systems. These may rely on internal, private data monitoring systems coupled with open data Geographic Information Systems (GIS) provided by government agencies to create better facility management and production processes, increasing productivity and reducing costs.

2.2. Smart Mobility

One of the key motivations of smart city projects is to improve the current state of congestion in most urban areas. Solutions range from autonomous vehicles that reduce the need for car ownership to deploying sensors in critical urban infrastructure such as roads, rails, subways, bridges, tunnels, seaports and airports. These sensors can provide valuable data on how to fluidify traffic, reduce accidents, improve public transport and make parking faster and easier. Out of 42 smart city projects studied by Dameri and Ricciardi (2017), almost half

(18) were focused on these types of solutions.

Long before self-driving cars become the norm, Vehicular Social Networks (VSNs) are emerging as one of the main short-term smart mobility trends (Ning et al., 2017). VSNs (such as the community around Google's Waze app) can integrate GPS data from thousands of real-time drivers and their smartphones with anomaly detection mechanisms (both human and algorithmic). In a near future, vehicle-to-vehicle and vehicle-to-infrastructure communication frameworks will complete this ecosystem to enable not only more accurate traffic information but also better cooperative navigation solutions, car sharing, theft control, safety warnings and cruise control.

Mobility should not only concern vehicles and infrastructure but above all quality of life of citizens. One of the less technological yet essential ingredients of mobility in smart cities is “walkability” (Kumar and Dahiya, 2017). Cities like Paris and Nice are decreasing the number of car lanes in key transit corridors to make way for pedestrians and bicycles. This effort to disincentivize motorized vehicles cannot be done without the careful study of traffic data and how to compensate with alternative routes as well as increased public transportation quality and availability. Barcelona, for instance, offers an augmented reality service to facilitate commuter's decisions such as finding the closest bus stops, metro stations, trams, and trains. The city is integrating data generated by different smart services into a unified urban mobility platform in partnership with Cisco (Zygiaris, 2013). Furthermore, walkability initiatives can be complemented by other ecological short-range mobility solutions such as electric bikes, scooters and mini-scooters shared through a free-floating, pay-per-use business model.

3. Innovation ecosystems in smart cities

As previously mentioned, the infrastructure of smart cities can create a unique collaborative ecosystem in which citizens, prosumers, industries, universities and research centers may develop innovative products, services, and solutions. Contrary to traditional double-sided marketplaces in which only two types of stakeholders participate (supply and demand), a smart city ecosystem involves a multitude of actors engaged in public and private consumption, production, education, research, entertainment and professional activities. This collaboration demands high levels of both human and social capital, as the innovation process is based on knowledge and learning (Smart People). In places where these Triple Helix dynamics is found (knowledge creation and knowledge application articulated by local government), creativity and innovation lead to more competitive and attractive local environments (Smart Economy). Both dimensions are discussed below.

3.1. Smart People

Smart cities can foster both human capital and social capital development (Toppeta, 2010). Human capital can be defined as the skills and competencies embedded in an individual or a group, whereas social capital is the quality and the number of links connecting social institutions. The interdependent nature of these two concepts is essential for understanding how smart cities increase productivity and innovation in local ecosystems.

According to Goldin (2016), the concept of human capital can be traced back to Adam Smith's Wealth of Nations. The pioneering work of Robert Solow in the 1950s demonstrated that the majority of productivity growth in society derived not as much from technology (capital) as from human knowledge and creativity, which are the two essential components of innovation. In smart cities, the presence of universities and other higher education institutions are essential to developing human capital, with clear impacts on economic growth as a result. Indeed, according to Shapiro (2006), growth in a metropolitan area's concentration of college-educated residents is directly correlated with employment growth. The same is not true of high school educated citizens, however; this result emphasizes the knowledge intensity required to increase employability.

As Florida (2014) warns, though, it is not sufficient to develop human capital, cities must retain and attract talent by making living there fun and engaging. Pittsburgh, for instance, has excellent universities but fails to create an innovative environment as dynamic as Boston's or San Francisco's, partly because it has a less exciting city life for young, talented graduates. Open minded, tolerant communities attract a diverse pool of creative workers, which are the basis for developing social capital in innovation ecosystems.

Social capital must be reinforced by carefully targeted public policies. By attracting talent and investments and providing high standards of living in terms of security, health and leisure infrastructure, cities become a natural environment for creative minds to gather, share and learn. Indeed, individual talent would not have as much economic impact without the institutional relations surrounding and binding them. Thus, according to Coleman (1988), whereas physical capital is embedded in material resources and human capital is embodied in the skills and knowledge acquired by an individual, social capital exists in the relationships of trust among persons and institutions. He argues that social capital is necessary to create human capital and vice versa. They are mutually reinforcing, as is exemplified in the case of “knowledge economy” initiatives discussed below.

3.2. Smart Economy

Thanks to the hardware infrastructure, on the one hand, and the social and human capital abundancy, on the other, smart cities can develop more competitive business environments. Thus, Smart Environment, Mobility and People are the basis for the innovative business models of the Smart Economy. Smart cities often create technology hubs to facilitate the sharing of knowledge in the forms of research centers, start-up incubators, and accelerators, as well as innovation parks. According to the Triple Helix perspective (Leydesdorff and Deakin, 2011), the physical proximity of talented individuals, innovative companies and government agencies can lead to a knowledge economy environment based on social networks of trust, sharing and learning.

A notorious example of the virtues of such a knowledge economy hub is The Research Triangle Park (RTP), implemented near the city of Raleigh in the 1960s. The RTP is credited as having been the main source of territorial economic growth in North Carolina in the last 60 years. According to Weddle (2009), before the RTP this region was one of the poorest in the Southeast, mostly a backwater tobacco farmland. Today, thanks largely to the successful attraction of companies like IBM, Cisco, Glaxo Smith Kline, and BASF and the resulting virtuous relationships (hiring, cooperative research) with the Universities of Duke, UNC and NCS, the region is one of the wealthiest, most creative hotspots for technology in the US. Such a success has inspired several Smart Cities to create knowledge economy initiatives to increase territorial attractiveness and thus create better quality jobs with all the positive externalities that entail (Luger and Goldstein, 1991).

Innovative cities and technology parks are natural magnets for open innovation projects. Schaffers et al. (2011) argue that when advanced IT infrastructures are developed locally by public-private partnerships, communities of lead users emerge both in companies and university labs. They cite the example of Nice in France, where a “living lab” was created around a green mobility project. This initiative involved the regional institution for air measurement quality, the local research institute dealing with the Internet of Things solutions (INRIA), the Internet Foundation for the New Generation, which facilitated workshops among local users, as well as a small company which provided access to electric cars, environmental data, and sensors. Citizens could participate in the project through the internet, developing Arduino-assembled kits to conduct experiments and by building their own sensors. In this co-creation process, users become “prosumers” and contribute directly to the development of the project. Such an initiative would not have been possible without the social and human capital surrounding the Technopole of Sophia Antipolis near Nice, where several of the participants were physically located. This kind of open innovation is facilitated by the synergy and creativity that emerge from open collaboration in the knowledge economy.

The ICT infrastructure of smart cities can also facilitate the emergence of innovative, cloud-based business models. Perera et al. (2014), for instance, mention the innovation possibilities created by Infrastructure-as-a-Service (IaaS), Platform-as-a-Service (PaaS) and Software-as-a-Service (SaaS) business models. These new services (often called XaaS for "Anything as a Service") can use the flexibility of cloud computing to create turn-key solutions to businesses and start-ups, reducing the entry barriers to develop new ideas and test new solutions for citizen well-being. Sensing-as-a-Service business models can, for example, use Open Data protocols from shared sensors infrastructure to gather real-time information about traffic, weather conditions, pollution, and logistics, making them available to companies or government agencies wishing to create smart services solutions. These business solutions can be provided by regional, national or multinational partnerships, which emphasizes the transboundary, hard *plus* soft nature of smart cities as previously discussed (Angelidou, 2014).

4. Quality of life in smart cities

As seen in the cases of Sophia Antipolis (France) and the Research Triangle Park (USA) briefly described above, the collaboration among knowledge workers (Smart People) to create an innovation ecosystem (Smart Economy) requires a great deal of local articulation among stakeholders (Smart Governance), often led by government agents or Public-Private Partnerships (PPPs). The decentralized nature of smart cities imposes effective coordination among hundreds of actors using an information and communication system that allows stakeholders to be aware of each other's movements and to facilitate active involvement and mutual support. In order to improve quality of life of a community through better services in the domains of health, public entertainment, and social bonding, real or virtual communities must be created and managed using state-of-the-art technology.

4.1. Smart Governance

According to the European Innovation Partnership on Smart Cities and Communities (EIP, 2013, p. 101), the role of Governance Entities is to "manage information flows among stakeholders, collecting/aggregating/processing data related to value-added processes in smart cities". GEs also may certify data quality and integrity, enable financial mechanisms, coordinate stakeholders (including citizens) throughout the value chains and generate both internal and external awareness about smart city initiatives. Typical roles in such Governance Entities include promoting, executing, financing, warrantying and certifying projects. Chourabi et al. (2012) also emphasize the role of these bodies in assuring transparency, accountability, communication, and participation among all organizations involved.

"Smart" Governance presupposes the innovative use of ICT infrastructure to achieve those goals, providing all stakeholders with a simplified, one-stop experience based on service application integration (Tokoro, 2015). Dustdar et al. (2017) argue that such a solution should involve the following tools: a) Data analytics and real-time process diagnosis: b) Activity coordination and social orchestration of smart city initiatives; c) Citizen communication; d) Infrastructure management and e) Services management; f) Incentives management. Far from a trivial integration effort, this convergence could be essential to create a central dashboard for governance and intelligence.

Incentives management is, to these authors, an essential ingredient of smart city governance. Indeed, based on evidence from the long-standing tradition of Self-Determination Theory (Ryan and Deci, 2000), they argue that government bodies should build both intrinsic (value-driven) motivation schemes as well as extrinsic ones (external rewards to compensate for the lack of intrinsic motivation) into their projects. Whereas intrinsic motivation (such as curiosity, altruism, competitiveness) is stronger and longer-lasting, it is harder to manage. It is more adapted to the left side of our hybrid model (live/play). Extrinsic motivation mechanisms (financial incentives, public sanctions) are more controllable, but also more volatile. They are more adapted to the right side of our model (work, learn).

4.2. Smart Living

The culmination of all the preceding layers is the well-being of citizens. The OECD (2017) defines well-being as a result of local material conditions, quality of life, and sustainability. This final section analyzes how Smart Environment, Mobility, People, Economy, and Governance may lead to Smart Living in modern cities. According to the OECD Better-Life Initiative framework (2017), smart living must include initiatives to improve health, education and social services and empower citizen participation (e-Government projects). It must have positive environmental impacts, reduce vulnerability and improve safety. Quality of life also should rely on better jobs, housing, and infrastructure (material conditions) as much on the preservation and development of natural, economic, human and social capitals.

All of these elements can be positively influenced by the use of information and communication technologies in smart cities. Indeed, we've seen how real-time information coupled with sophisticated algorithms can improve the energy infrastructure, monitor environmental threats and fluidify public transit (Smart Environment and Mobility); how it can help create value through better collaboration and innovation tools for learning and working (Smart People and Economy) and how all of these efforts can be coordinated through centralized Smart Governance tools.

Dameri and Ricciardi (2017) cite two examples of Smart Living solutions (out of 24 projects identified in this category in their survey). In Spain, several cities have adopted a centralized digital solution to deliver real-time information about beach quality, mobility, touristic infrastructures, and public services. In the case of Rome, a platform was created to facilitate the relationship between citizens and government agencies, supporting entrepreneurship, events management, city security, and tourism. The other examples cited in this text complete the picture of how infrastructure and innovation through better information systems can lead to a better quality of life in smart cities.

5. Overview of the special issue contributions

5.1. Descriptive statistics

Following an extensive blind peer-review process a total of thirty-one papers were accepted for inclusion to the special issue, on the basis of established selection criteria: novelty and originality of the discussed topics, methods, and/or approaches; overall consistency with the aims of the call for papers; relevance both for the academic and practitioner debates. As editors of the special issue, we would like to take this opportunity to thank all the reviewers involved in the process for their constructive feedback during the multiple review rounds. Table 2 provides an overview of the universities/research centers/companies, departments, countries, and number of co-authors for each special issue paper.

We received contributions from twenty-one countries; approximately 45% of the researchers work in institutions located in Italy, United Kingdom, and The Netherlands. A total number of twenty-nine among scholars and practitioners wrote for this special issue, with an average of 3.4 authors per paper; 60% of the contributions have been co-authored by no more than three co-authors, whereas 7% by a single author, and 14% by six authors. In terms of institutions and

Table 2
Descriptive statistics of accepted contributions.

Title	Universities, companies	Departments	Countries	#Co-authors	#Universities/ Companies	#Departments
Business models for developing smart cities. A fuzzy set qualitative comparative analysis of an IoT platform	University of Messina	Department of Economics; Department of Mathematical Sciences, Physical Sciences, and Earth Science	IT	4	1	2
Centralized simulated annealing for alleviating vehicular congestion in smart cities	University of Sheffield	Department of Automatic Control and Systems Engineering	UK	6	4	4
	Southern Technical University	Technical Institute Qurna	IQ			
	UAE University	College of Information Technology	AE			
	University of Leeds	Electronic and Electrical Engineering School	UK			
Reframing technologically enhanced urban scenarios: A design research model towards human centered smart cities	Harvard University	Harvard Graduate School of Design	USA	4	2	2
	University of Bergamo	Department of Management, Information and Production Engineering	IT			
The role of universities in the knowledge management of smart city projects	Politecnico di Bari	Department of Mechanics, Mathematics and Management	IT	5	6	6
	Campus “Bio-Medico” University of Rome	Departmental Faculty of Engineering	IT			
	University of Turin	Department of Management	IT			
	Ural Federal University	Graduate School of Economics and Management	RU			
	Link Campus University	Management, Economics and Local Development Research Center	IT			
	PSB Paris School of Business	Department of Management and Strategy	FR			
Light the way for smart cities: Lessons from Philips Lighting	Eindhoven University of Technology	Innovation Technology Entrepreneurship & Marketing	NL	5	3	3
	Alliance for Internet of Things Innovation & InnoAdds		NL			
	Tilburg University	Jheronimus Academy of Data Science	NL			
Driving elements to make cities smarter: Evidences from European projects	Federal University of Rio Grande do Sul	NITEC — Innovation Research Center	BR	3	1	1
Smart innovative cities: The impact of Smart City policies on urban innovation	Politecnico di Milano	Department of Architecture, Construction Engineering and Built Environment	IT	2	2	2
	Università degli Studi di Milano	Department of Economics, Management and Quantitative Methods	IT			
Economic and policy uncertainty in climate change mitigation: The London Smart City case scenario	Radboud University	Institute for Management Research	NL	2	2	2
	Léonard de Vinci Pôle Universitaire	Research Center, Finance Group	FR			
Participatory energy: Research, imaginaries and practices on people' contribute to energy systems in the smart city	Scuola Superiore Sant'Anna	Institute of Management	IT	3	3	3
	Ghent University	Center for Sustainable Development – CDO	BE			
	University of Waikato	Faculty of Science and Engineering	NZ			
Understanding smart cities as a glocal strategy: A comparison between Italy and China	University of Genoa	Department of Economics and Business Studies	IT	4	3	3
	University of Uninettuno	Department of Economics	IT			
	Jiangsu University	School of Finance and Economics	CN			
Understanding user representations, a new development path for supporting Smart City policy: Evaluation of the electric car use in Lorraine Region	Université de Lorraine	Laboratoire ERPI	FR	4	1	1
Excluding citizens from the European smart city: The discourse practices of pursuing and granting smartness	Erasmus University Rotterdam	Erasmus School of History, Culture and Communication; Centre for BOLD Cities and the Department of Public Administration and Sociology; Rotterdam Knowledge Lab of Urban Big Data and Erasmus Graduate School of Social Sciences and the Humanities	NL	3	1	3
A Multiple-Attribute Decision Making-based approach for smart city rankings design	University of Castilla-La Mancha	School of Computing Science; The Energy Research and Industrial Applications Institute (INEI)	ES	6	1	2
Heuristic for the localization of new shops based on business and social criteria	La Salle - Ramon Llull University	Department of Management	ES	3	3	3
	Universitat Politècnica de Catalunya BarcelonaTech, ETSEIAT	Department of Management	ES			
	IESE Business School	Department of Management	ES			
The relationship between regional compactness and regional innovation capacity (RIC): Empirical evidence from a national study	University of Texas at Arlington	College of Architecture, Planning and Public Affairs	USA	3	1	1
Investigating ‘anywhere working’ as a mechanism for alleviating traffic congestion in smart cities	Swinburne University of Technology	Department of Business Technology and Entrepreneurship	AU	2	1	1

(*continued on next page*)

Table 2 (*continued*)

Title	Universities, companies	Departments	Countries	#Co-authors	#Universities/ Companies	#Departments
A cross-disciplinary path to healthy and energy efficient buildings	University of Copenhagen	Department of Anthropology	DK	6	3	3
	Danish Technological University	DTU Compute	DK			
	Municipality of Høje Taastrup	Center of Technique and Environment	DK			
Intermediaries for knowledge transfer in integrated energy planning of urban districts	Norwegian University of Science and Technology	Department of Architecture and Planning	NO	6	2	2
	Austrian Institute of Technology	Sustainable Buildings and Cities	AT			
Combining co-citation clustering and text-based analysis to reveal the main development paths of smart cities	Edinburgh Napier University	The Business School; School of Engineering and the Built Environment	UK	3	2	2
Strategic principles for smart city development: A multiple case study analysis of European best practices	Edinburgh Napier University	The Business School; School of Engineering and the Built Environment	UK	3	2	2
Enhancing social networking in smart cities: Privacy and security borderlines	Aristotle University of Thessaloniki	Centre for Research & Technology Hellas (CERTH), Information Technology Institute; Department of Informatics	GR	5	3	4
	SignalGeneriX Ltd.		CY			
	TEI of Thessaly		GR			
To the smart city and beyond? Developing a typology of smart urban innovation	Nord University	Faculty of Social Sciences	NO	1	1	1
Implementing citizen centric technology in developing smart cities: A model for predicting the acceptance of urban technologies	UNSW Sydney	Smart Cities Research Cluster UNSW	AU	4	3	3
	Isfahan University of Art	Faculty of Architecture and Urban Planning	IR			
	Tarbiat Modares University	Faculty of Architecture and Art	IR			
Towards the smart city 2.0: Empirical evidence of using smartness as a tool for tackling social challenges	Tohoku University	Graduate School of Environmental Studies	JP	1	1	1
An exploration of smart city approaches by international ICT firms	Amsterdam University of Applied Sciences	University of Amsterdam Business School	NL	2	1	1
Navigating platform urbanism	Vrije Universiteit Brussel	imec-SMIT	BE	2	1	1
Measuring the extent to which Londoners are willing to pay for public art in their city	MTArt Agency		UK	2	2	3
	Sotheby's		UK			
	The Bartlett, University College London	Centre for Advanced Spatial Analysis	UK			
Business Model Innovation for Urban Smartization	Parthenope University	Department of Management and Quantitative Sciences (DISAQ)	IT	3	3	4
		Department of Business and Economic Studies (DISAE)	IT			
	PSB Paris School of Business		FR			
	Luiss University	Department of Business and Management	IT			
Municipalities' understanding of the Smart City concept: an exploratory analysis in Belgium	HEC Liége	Smart City Institute; Management School of the University of Liége	BE	3	2	3
	Technical University of Wien	Department of Spatial Planning	AT			
Identifying and supporting exploratory and exploitative models of innovation in municipal urban planning; Key challenges from seven Norwegian energy ambitious neighborhood pilots	Norwegian University of Science and Technology	Department of Architecture and Planning	NO	3	2	2
	SINTEF Building and infrastructure		NO			
Towards a service-dominant platform for public value co-creation in a smart city: Evidence from two metropolitan cities in China	University of Chinese Academy of Sciences	Institutes of Science and Development, Chinese Academy of Sciences;	CN	4	1	1

departments, two universities/companies and two departments on average worked together to build up the study, with a maximum of six. It is worthy of notice the level of interdisciplinarity in undertaking such an endeavor: among the many disciplines, we highlight management, economics, mathematics, computer science, art, engineering, innovation, architecture, design, sustainability, history, energy, and anthropology. Under these respects, the spirit of the call for papers was successfully accomplished since its aim was to stimulate interdisciplinary collaboration and build up a community to enact a constructive discourse around Smart Cities.

5.2. Reviewing the content

The thirty-one papers comprising this special issue advance our understanding of the underlying technological and societal challenges smart cities initiatives pose to academics, practitioners, and policy makers. It is worth noting that this collection of papers is heterogeneous in terms of theoretical approaches, empirical methodologies, and focus of the investigation, spanning a wide range of conceptual approaches and research designs. In so doing, it exposes the reader to diverse ideas and methods, thus having the potential to stimulate creative scholarly conversations on the topic (Table 3).

In detail, more than one-third of the sample (i.e. twelve papers) provides the reader with some conceptualizations, approaches, and typologies to read and interpret the smart cities phenomenon through more critical lenses. Andreani et al. (2018) argue about how to move the locus of inquiry from a technocentric and universalist approach on smart cities – mainly predictable, overplanned, top-down, efficient, and quantitative – towards a design-driven and human-centric approach – which is more unintentional, temporary, democratic, creative, and qualitative. Drawing from research pursued within the 'Real Cities/ Bergamo 2035' joint initiative between the University of Bergamo and the Graduate School of Design at Harvard University, authors focused on mid-sized European cities; three scenarios were investigated: the adaptive street environments, the responsive urban safety, and the dynamic retail spaces. The proposed model is articulated into three interwoven components: a grounded vision, addressing the ideation of alternative futures that stem from specific needs or local opportunities; an embraced technology, elaborating on the role played by urban technologies in augmenting the inner intelligence of places; and an urban co-evolution, fostering a mutually-constructive interaction between the urban players (i.e. citizens, researchers and designers, and stakeholders) for collaborative innovation. Dameri et al. (2018) conceptualize smart cities as a glocal strategy. A smart city is global since it is a phenomenon spreading all over the world, with some shared features and interdependencies: they attract investments, talents, and innovative firms; however, it is a local phenomenon as each city shows unique characteristics and problems policy makers can only deal with by means of specific solutions: it suffices to think about the geographical and territorial specificities, the cultural milieu, the needs and traditions of the communities. By comparing Italian (Bologna, Milan, Turin, Florence, and Genoa) and Chinese (Shanghai, Beijing, Tianjin, Guangzhou, and Chengdu) cities, authors develop a theoretical framework based on four dimensions: people (smart citizens; smart city actors such as firms, universities, private bodies; people involvement), government (political institutions; powers distribution; smart city governance processes; priorities), infrastructure (better use of energy; renewal energy source; buildings efficiency; efficient services like transport), and land (environmental and geographical aspects; cultural history and heritage; logistics). It results that the Italian and Chinese smart city implementation path differ since the former exhibits a bottom-up approach as a result of the following local drivers (existing infrastructures, lack of a national smart city strategy, decentralized governance, lack of funding to support smart cities initiatives), whereas the latter follow a top-down approach deriving from a national smart city strategy. Escolar et al. (2018) review the existing ranking for smart cities highlighting

Table 3
Overview of the contributions in the light of our hybrid framework (Fig. 1).

Title	Focus
Business models for developing smart cities. A fuzzy set qualitative comparative analysis of an IoT platform	PI/IE/QL
Centralized simulated annealing for alleviating vehicular congestion in smart cities	PI
Reframing technologically enhanced urban scenarios: A design research model towards human centered smart cities	PI/IE/QL
The role of universities in the knowledge management of smart city projects	IE/QL
Light the way for smart cities: Lessons from Philips Lighting	IE/QL
Driving elements to make cities smarter: Evidences from European projects	PI/IE/QL
Smart innovative cities: The impact of Smart City policies on urban innovation	PI/IE/QL
Economic and policy uncertainty in climate change mitigation: The London Smart City case scenario	PI/QL
Participatory energy: Research, imaginaries and practices on people' contribute to energy systems in the smart city	PI/IE
Understanding smart cities as a glocal strategy: A comparison between Italy and China	PI/IE/QL
Understanding user representations, a new development path for supporting Smart City policy: Evaluation of the electric car use in Lorraine Region	PI/QL
Excluding citizens from the European smart city: The discourse practices of pursuing and granting smartness	IE/QL
A Multiple-Attribute Decision Making-based approach for smart city rankings design	PI/IE/QL
Heuristic for the localization of new shops based on business and social criteria	IE/QL
The relationship between regional compactness and regional innovation capacity (RIC): Empirical evidence from a national study	IE
Investigating 'anywhere working' as a mechanism for alleviating traffic congestion in smart cities	PI/QL
A cross-disciplinary path to healthy and energy efficient buildings	PI/QL
Intermediaries for knowledge transfer in integrated energy planning of urban districts	PI/QL
Combining co-citation clustering and text-based analysis to reveal the main development paths of smart cities	PI/IE/QL
Strategic principles for smart city development: A multiple case study analysis of European best practices	PI/IE/QL
Enhancing social networking in smart cities: Privacy and security borderlines	IE/QL
To the smart city and beyond? Developing a typology of smart urban innovation	PI/IE/QL
Implementing citizen centric technology in developing smart cities: A model for predicting the acceptance of urban technologies	PI/IE/QL
Towards the smart city 2.0: Empirical evidence of using smartness as a tool for tackling social challenges	PI/IE/QL
An exploration of smart city approaches by international ICT firms	IE/QL
Navigating platform urbanism	PI/QL
Measuring the extent to which Londoners are willing to pay for public art in their city	IE/QL
Business Model Innovation for Urban Smartization	IE
Municipalities' understanding of the Smart City concept: an exploratory analysis in Belgium	PI/IE/QL
Identifying and supporting exploratory and exploitative models of innovation in municipal urban planning; Key challenges from seven Norwegian energy ambitious neighborhood pilots	PI/IE/QL
Towards a service-dominant platform for public value co-creation in a smart city: Evidence from two metropolitan cities in China	PI/IE/QL

their major weaknesses in the overlook of technological criteria. To fill this gap, they advance a methodological approach for developing smart cities rankings based on technological and smartness criteria; they do it by applying a multi-attribute decision making-based approach (MADM). The smartness dimension authors propose considers thirty-eight ICT indicators related to the main enabling technologies for smart cities realization: sensors and actuators, networking, platforms and services deployed, applications, standardization level, and metrics to determine their impact on the city. By testing their method on three case studies (Seoul, Santander, and New York), authors highlight its strengths (i.e. coherence with the most commonly accepted vision of the IoT and smart cities, set of new ICT and smartness indicators, and easy extension with new indicators) and weaknesses (i.e. subjectivity of the MADM method, limited number of cities involved in the ranking). Mora et al. (2018a) rely on two hybrid techniques to unveil the main development paths of smart cities; precisely, they combine co-citation clustering and text-based analysis to perform their bibliometric study (Appio et al., 2014, 2016; Glanzel and Thijs, 2011). They show that research on smart cities is diverging into five development paths: experimental, ubiquitous, corporate, European, and holistic. Importantly, four main dichotomies emerge which are mainly rooted into the cognitive-epistemological structure of the smart city research and challenge the scientific community: techno-led or holistic, top-down or bottom-up, double or triple/quadruple helix, mono-dimensional or integrated. The ambiguity generated by these dichotomies challenges policy makers in setting a proper smart cities development agenda. Moving from the need deal with these dichotomies, Mora et al. (2018b) investigate the validity of the strategic principles for smart city development by comparing four cities considered to be leading examples of European smart cities: Amsterdam, Barcelona, Helsinki, Vienna. Through a best practice analysis, the authors identify six strategic principles to support the decision-making process and speed up the effective deployment of smart technologies in European urban environments: look beyond technology; move towards a quadruple-helix collaborative model; combine top-down (government-led) and bottom-up (community-driven); build a strategic framework; boost the digital transformation by establishing a smart city accelerator; adopt an integrated intervention logic. In reviewing what constitutes the smart in smart cities, Nilssen (2018) concluded that the concept of smartness should be understood as a collection of developmental features; smart cities initiatives have to be able to effectively connect the wide range of existing activities, adopting a holistic approach. The latter should be based on a typology of smart urban innovations based on new technological practices, products, and services; organizational project-based levers internal to the municipal organization; public-private networks and triple helix collaborative models; and a rhetoric dimension inspiring the vision of an innovative urbanism. She discusses her typology in the light of the smart cities initiatives in the city of BodØ (Norway). Sepasgozar et al. (2018) advance a new Urban Services Technology Acceptance Model (USTAM), which is aimed at assisting governments and business to develop appropriate 'urban service' technologies for local contexts and emerging economies. Major emphasis is posed on the relevance of local knowledge as a source of innovative potential for smart cities. Their model is able to assess to what extent the behavior intention to use UST is influenced by factors such as service quality, self-efficacy, a number of TAM factors (i.e. perceived security, relative advantages, perceived of use, perceived usefulness, compatibility, reliability), as well as factors stemming from the social cognitive theory (i.e. work facilitating, cost reduction, energy saving, and time saving). Trencher (2018) argues about the need to move from a smart city 1.0 approach towards a smart city 2.0. A smart city 1.0 revolves around a centralized approach with exogenous development has at its focus the diffusion of smart technologies for corporate and economic interests; the role of citizens is rather passive; the objective of the technology and experimentations is to optimize infrastructures and services, serve the demand side interests and spur new business opportunities, and address the universal technical agendas (energy, transport, economy). On the contrary, a smart city 2.0 approach is focused on people, governance, and policy; citizens have an active role as co-creators of innovations, problem solvers, and planners; the objective of technology and experimentation is to mitigate or solve social problems, enhance citizens' wellbeing and public services, and address specific endogenous problems and citizen's needs. Smart city 2.0 is clearly a decentralized approach in which diverse actors are involved and the development is endogenous to the system. Then, the author explains how the concept of Smart City 2.0 works by looking at the case of a Japanese city – Aizuwakamatsu – where explicit attention to tackle social issues and address citizens' needs is articulated and formalized in project documents. Desdemoustier et al. (2018) investigate how – and to what extent – 113 Belgian municipalities understand the concept of Smart Cities. Findings suggested the creation of a typology of understandings comprising four dimensions: technological (a technology implementation), societal (a human, sustainable and institutional positioning), comprehensive (an integration of technology, human-centricity, sustainability, and institutional factors) and non-existent (an absence of understanding). Interestingly, municipalities engaged in comprehensive understanding find setting up smart city projects highly difficult; those with non-existent knowledge do not adhere to the phenomenon. Nielsen et al. (2018) read the smart cities phenomenon through the lenses of the ambidextrous organizations. Through a multiple cases analysis, they study seven pilot projects in Norwegian municipalities, developers, and universities. They find that developing an ambidextrous capability alongside leveraging upon a bottom-up capacity building could be the right way to adapt recent technological advancements to emerging smart cities programs. Camboim et al. (2018) come up with an integrated framework to make a city smarter on the basis of extant literature, interviews with experts, and insights from four smart cities projects (Amsterdam, Barcelona, Lisbon, Vienna). Their framework identified three steps: smart strategies, where governance takes the lead of the transformation process from a traditional city into a smart city; smart projects, in which socio-institutional, techno-economic and environmental and urban factors are the main drivers; and smart performance inflected in terms of sustainable socioeconomic development. Finally, Yu et al. (2018) argue about the possibility to adopt the concept of service dominant platform (SDP) to help the city stakeholders to co-create smart cities. By combining the foundational elements of the service-dominant logic (SDL) with platform theory, they propose three dynamic conceptual pillars play a role: value proposition, value in exchange, and value in use, consisting of ten sub-elements articulated on four dimensions namely, openness, services innovation, governance, and resources. Findings from a business-oriented platform in Guangzhou (i.e. WeChat) and a government-oriented platform in Shanghai (i.e. Citizen Cloud) show that smart city initiatives subsume the multi-parties formulation of a co-creation sustainable strategy.

The remaining papers (i.e. nineteen) can be grouped into four clusters labeled as follows: business models for smart cities (Abbate et al., 2018; Brock et al., 2018; Schiavone et al., 2018; Van den Buuse and Kolk, 2018); applications to tackle specific smart cities challenges (Amer et al., 2018; Grimaldi et al., 2018; Hopkins and McKay, 2018; Lex et al., 2018; Moustaka et al., 2018; Tanguy and Kumar, 2018); actions and roles of stakeholders of the smart cities triple/quadruple helix (Ardito et al., 2018; Corsini et al., 2018; Dupont et al., 2018; Engelbert et al., 2018; Lindkvist et al., 2018; Van der Graaf and Ballon, 2018); policies for smart cities (Caragliu and Del Bo, 2018; Contreras and Platania, 2018; Hamidi et al., 2018).

Concerning the first cluster – business models for smart cities – Abbate et al. (2018) explore the activities and strategic goals of twenty-one small and medium enterprises (SMEs) operating in eight different European countries that took part to *FrontierCities*, one of the nine FI-WARE (Future Internet-ware) Accelerators focused on smart cities. The aim is understanding what type of business models they can adopt when exploiting the technological potential of an IoT platform. Authors reveal that only key resources can be considered as the core element in the customized products and service business model, while key activities and key partners stand as complementary variable; then, when firms aim at developing smart cities projects have to consider the cooperation with customer capabilities as the main key resources; customers become an important part of the puzzle in order for firms to deploy proper business models. By carrying out an in-depth case study at Philips Lighting, Brock et al. (2018) show what type of business models are relevant for the smart city market. Philips is searching for new ways to create and capture value within different smart city ecosystems; four of them – Amsterdam, Eindhoven, Stratumseind, and Veghel – are instrumental to unveil the main business models: marbles business model, in which there is no integration of value creation or value capture activities between the different parties, and everything is developed inhouse and sold as a one-off sale; Tetris business model, where value is created individually, while an extended set of revenue models are introduced that build on each other and can be shared across the ecosystem; Jenga business model, characterized by an extended value creation, where different ecosystem actors learn from each other, though with limited revenue potential for the individual parties; finally, the Jigsaw Puzzle business model, in which we have an extended value creation and value capture, by leveraging synergies within an ecosystem to jointly create the most value for customers and the ecosystem. Schiavone et al. (2018) apply the business model canvas to the smart cities literature. They identify the revenue stream, cost structure, key resources, key activities, key partners, the value creation, customer relationships, market segments, and channels identifying the basic building blocks of the smart city business model canvas. Finally, Van den Buuse and Kolk (2018) investigate the strategic approaches three multinational enterprises (MNEs) from the ICT industry (IBM, Cisco, Accenture) adopt as suppliers of smart city technologies. Evidence from firm-specific programs like IBM's Smarter Cities, Cisco's Smart + Connected Communities, and Accenture's Intelligent Cities, shows that both non-location-bound firms specific advantages (e.g., building resources and capabilities in management from heterogeneous urban contexts, building a position as international smart city technology supplier in a potential growth market, exploring complementarities between existing resources and capabilities in ICT and urban domains, among others) and location-bound firms specific advantages (e.g., building relationships with city governments in prime cities for the spread of smart cities technologies, building expert knowledge of specific urban system and infrastructures in a local context, gaining access to local knowledge clusters and urban stakeholders in a local context) are relevant components of the three MNEs' business models.

In the second cluster – applications to tackle specific smart cities challenges – Amer et al. (2018) introduce a new method in order to alleviate vehicular traffic congestion in smart cities. This method is a centralized dynamic multi-objective optimization algorithm based on vehicular ad hoc networks (VANETs); it integrates a centralized simulated annealing (CSA) algorithm with the VIKOR method as a cost function. The aim of the CSA-VIKOR method is to provide the drivers with the optimal paths according to multiple criteria in order to meet the diverse navigation requirements of the drivers. The optimization algorithms, tested into the city centers of Turin and Birmingham, results in journeys improvements concerning the minimum travel time, the minimum travel distance, the minimum fuel consumption, the minimum amount of emissions, or a combination of the four. Still on traffic congestion, this time in Melbourne, Hopkins and McKay (2018) explore the role of environmental factors (climate change, global warming, greenhouse gas emissions, atmospheric issues), economic factors (service economy, information-based work activities, decoupling work task from place, skill, and performance-based work), technological factors (widespread access to Internet, dematerialization, employee flexibility, bring-your-own-device practices, distributed teams) on the 'anywhere working' practices (worker attitudes towards adoption, and current commuter behavior). In turn, they also assess the benefits and constraints of the 'anywhere working.' The heuristic proposed by Grimaldi et al. (2018) deals with the desertification of urban areas due to the massive close of local shops in contexts hit by the financial crisis. Their heuristic entails business and social criteria and results coming from the computational experiment run in the Sant Andreu district (Barcelona) show that an effective smart city policy faces urban degeneration by decreasing the risks of uniformity, monobusiness activity, and gentrification of the neighborhood. Another contribution comes from a cross-disciplinary collaboration framed within four sub-themes: local energy systems, indoor climate in buildings, social and organizational conditions, and political circumstances (Lex et al., 2018). Authors propose a digital platform to deal with the indoor climate in public buildings in Copenhagen and argue about the importance to enacting micro-social cross-boundary collaborations among all the involved stakeholders as a way to create concrete scientific and practical insights on smart city development initiatives. By analyzing the case of Trikala (Greece), Moustaka et al. (2018) pay attention to the publicly available data generated by people and shared on online social networks (OSN), providing measures to improve their privacy and security, smoothening the risks, and boost community's engagement in smart cities. OSN is conceptualized as sensors of urban dynamics with unquestionable advantages but not negligible threats and vulnerabilities. The interactions between smart people/smart living and privacy/security concerns are discussed and a multi-stage behavioral pattern model is advanced. Participation on OSN, education, and training for secure behavior, tools and software for privacy and security protection, data privacy legislative framework lead to better key performance indicators in smart cities. Finally, Tanguy and Kumar (2018) give to art projects the role extant literature on smart cities neglected. They explore the impact of public art projects on the life and demand of citizens in London. By collecting data from two public art initiatives organized by the MTArt Agency they show that Londoners are willing to pay for more public art in local areas; furthermore, these projects call for a transversal involvement of art experts, urban planners, economists, sociologists, political scientists, and citizens.

The third cluster discusses the actions and roles of stakeholders of the smart cities triple/quadruple helix. Ardito et al. (2018) argue that knowledge-based urban development (KBUD) frameworks are increasingly permeating the smart cities debate. They outline a 2 × 2 matrix on the basis of two dimensions: knowledge management (KM) issues, where project partners may address KM governance in different ways and KM processes can change according to the knowledge domain; knowledge management domains, by considering whether knowledge stems from similar or distant fields. A first quadrant captures KM governance when knowledge of project partners is used; the second quadrant analyzes KM governance when external knowledge is used; the third quadrant focuses on KM processes in cases of knowledge coming from project partners; a final quadrant presents cases of KM processes when external knowledge is used. By selecting cases of smart cities initiatives from Italian, English, American, Spanish, and Belgian cities, they investigate the role of universities (i.e. knowledge intermediary, provider, evaluator, gatekeeper in the triple or quadruple helix configurations). Engelbert et al. (2018) focus their study on the role of citizens in the smart cities discourse. Moving from a characterization of a smart city as an assemblage of 'peripheral' smart city network practices and 'central' smart city project practices, they critically examine the political-economic ambitions of those cities able to grant the recognition 'smart' (i.e. European Research and Innovation Schemes) and those needing to 'pursue' it (i.e. post-crisis municipalities). Through such a differentiation, they figure out why the majority of the smart cities initiatives tend to exclude the needs and interests of citizens. Still focusing on the role of citizens, Dupont et al. (2018) investigate the user representations French citizens in the Lorrain Region have when they confront with specific technologies like electric cars. Four complementary aspects characterize the social representation: the possibility of action of the subject on the system, the stimuli caused by the system, how the user will identify with the system, as well as the overall attraction. Authors were also able to qualify the pragmatic and hedonic attributes of the relationship between potential users and the image and attractiveness of the electric cars. Corsini et al. (2018) still focus on the role of citizens in contributing to the energy systems in a smart city initiative. Through a bibliometric analysis and visual representation (Appio et al., 2017, 2017; Van Eck and Waltman, 2010) of an overall set of 74,932 academic papers, they show that city dwellers are rarely at the core of energy transition agendas. Instead, research overemphasizes the role of technological advancements for energy production and consumption. Authors argue about those socio-technical imaginaries that put citizens at the core of a participatory smart city revolution. Still concerning energy planning practices in urban districts, Lindkvist et al. (2018) examine the role of intermediaries for knowledge transfer in early, progressed, and implemented project stages. Findings from ongoing projects based in Norway, Spain, France, Sweden, and Austria, show that intermediaries are absent in the fuzzy front end of the project while showing up later as problem solvers. Authors call for more integrated planning practices in which intermediaries become part of the helix of stakeholders since the very early stages of the process. Finally, Van der Graaf and Ballon (2018) investigate the role of a social traffic and navigation application, Waze, operationalizing the concept of platform urbanism in which citizens, private and public organizations interact. By exploring the manifestations of dynamics in mobility practices occurring between commerce and community in the city, they found out a (complex and new) socio-spatial construct is emerging. Important questions arise concerning the role of urban and transportation management and planning in the public space of the city.

In the fourth cluster, which emphasizes the policies for smart cities, Contreras and Platania (2018) investigate the role of policies in climate change in the London Environment Strategy (LES) within the London smart city initiative. By using a zero mean-reverting model for greenhouse gas emissions, the quantitatively analyze the consistency of the LSE framework with the 2020 Zero Carbon objectives. Different policy scenarios are considered by focusing on the domestic, industrial and commercial, and transport sectors. Their simulation study shows that considering the 2000–2014 greenhouse emission trend, the industrial and commercial sector and the domestic sector present levels far from the 2050 zero level objective; only the transport sector improves the historical trend. This is the result of the smart mobility and smart environment policies proposed within the LSE framework. Caragliu and Del Bo (2018) assess the impact of smart cities policies on urban innovation. They collect data from 309 European metropolitan areas on the basis of six axes: human capital, social capital, transport infrastructure, ICT infrastructure, natural resources, and e-government. Results from the propensity score matching estimates show that smart city policies do have a non-negligible positive impact on urban innovation measured through patenting activity, especially in high-tech classes. They also show that these policies stimulate innovation, which in turn increases the city's stock of knowledge. Finally, Hamidi et al. (2018) explore the link between regional compactness and the regional innovation capacity (RIC). Compact urban forms are characterized by walkability, higher street connectivity, and greater accessibility to urban amenities, jobs-housing balance, and mixed land use in addition to density. They measure regional compactness by borrowing the recently released Metropolitan Compactness Index (MIC), which includes 21 built environmental features and captures several dimensions of sprawl. Their study finds that all the three RIC indicators – the average number of patents, firm innovations, and number of innovative small firms – are positively associated with regional compactness. Their findings have an impact on the physical and social landscapes of cites, call for investments in increasing accessibility and improving public transit as factors contributing to agglomeration economies and innovation production.

6. Towards a research agenda

Despite the value of the thirty-one articles presented, this special issue leaves space for scientists, practitioners and policy makers to further explore the subject of smart cities.

One research avenue could deal with the *risks and benefits* of implementing smart cities initiatives. In fact, in this paper we have discussed mostly the potential benefits of smart cities. However, one must keep in mind the dangers and threats posed by this explosion in data and algorithms. Among the risks cited in the literature are ideological manipulation (Morozov and Bria, 2018), the corporatization of city governance (Paroutis et al., 2014; Söderström et al., 2014), hackable networks vulnerable to cyber-attacks and a tendency to normalize a surveillance state (Bauman and Lyon, 2013; Ellul, 2012; Kitchin, 2014). Surveillance come from the need of security and the means to reach it are the new available techniques and technologies (Bauman and Lyon, 2013); and if we consider that we moved from an era in which threats came from outside the city to a world in which threats come from within the city, the risk to build a Panopticon society (Lyon, 2006) is seducing. According to Lehr (2018), a city cannot be called 'smart' unless it has solved the complex issues associated with privacy in a world of ubiquitous data, social interactions, and artificial intelligence. Perera et al. (2014) list a series of challenges facing smart cities in the domains of technology (lack of integration across government systems, interoperability, standardization, availability and compatibility of software, systems and applications); security and privacy (threats from hackers and intruders, threats from viruses, worms and trojans; breach of privacy, theft of personal data) and socio-cultural barriers (trust, social acceptance, resistance to change, usability, digital illiteracy). These barriers cannot be overcome simply with technological solutions. They must be followed by legal frameworks such as Europe's General Data Protection Regulation (EU, 2016), active policies for developing human and social capitals through training programs, civic awareness campaigns and curriculum reforms in schools and universities. They have to articulate and engage all stakeholders in the public and private sectors, develop standards and protocols, facilitate bottom-up as well as propose top-down guidelines. Therefore, Smart Governance (e.g., Ruhlandt, 2018) emerges probably as the key factor mediating the other dimensions of the model in order to assure that projects remain within *ethical boundaries*, that stakeholders constantly communicate and learn from each other and that the resulting products and services ultimately have a positive impact on the well-being of smart city dwellers. International standards for smart cities (such as ISO 37122) could provide basic guidelines to all stakeholders involved.

Future studies could focus on examining the ways actors, groups, organizations and stakeholders develop strategies (Paroutis et al., 2014) to deal with the risks and benefits associated with smart cities. The contradictory but interrelated nature of smart city objectives means that studying them could benefit from recent advancements found in ambidexterity and paradox studies (Knight and Paroutis, 2017; Lewis, 2000; Papachroni et al., 2016; Smith, 2014), for example by studying the rhetorical practices groups and organizations develop over time to deal with the tensions associated with smart city initiatives (Bednarek et al., 2017). Another area of research could conceptualize and study smart cities as business ecosystems and platforms (Jacobides et al., 2018; Kretschmer and Claussen, 2016) where multiple actors and organizations act and interact over time to implement innovative solutions (Kumaraswamy et al., 2018). For such future studies, the hybrid model we proposed earlier (see Fig. 1) can assist scholars and policy makers visualize and appreciate the interdependent nature of physical infrastructure, innovation ecosystems and quality of life in smart cities. Overall, understanding the processes and practices related with the social challenges and impact of smart cities represents a fundamental area for future research (Burgelman et al., 2018). Such research endeavors will be impactful in providing stakeholders, policy makers and social actors with the means, processes and technological solutions to measure and then improve the social impact of smart city initiatives.

Another risk class to be considered deals with the transformation of the urban landscape. Contributions and intellectual leaps are necessary to introduce and contrast utopian and dystopian representations of the intelligent city in the XXII century. Essays like the one written by Wells in 1897 can be of inspiration to see how – and to what extent – urban transformations which tend to pose too much emphasis on the technocracy show huge social inequalities, overcrowded skyscrapers in few megalopolis crossed by congested air traffic, with countryside completely abandoned, few big corporations managing the world economy, and citizens living and working under an uncontrollable mental hypnosis. Driving the debate outwards to present the emergence of Orwellian scenarios can help policy makers to focus their actions on more utopian models of intelligent cities.

Relatedly, and asking how we should live in the city, Sennett (2012, 2018) looks at the city as an 'open city' that embeds complexity, ambiguity, and uncertainty. By distinguishing between two aspects of the city, namely the *ville*, which refers to the built environment, and the *cité*, which refers to the modes of life and place attachments to which urbanity leads, Richard Sennett explains why long-term and large-scale urban planning is difficult. This frustration is rooted into the huge divide between the *ville* and the *cité*, which traces back to the nineteenth century when Baron Hausmann's boulevards, Ildefons Cerdà's *Eixample* in Barcelona, and Frederick Olmsted's Central Park were mainly aimed at refashioning neglecting the way people behave in the city. This divorce went on in the twentieth century with the Chicago School, Le Corbusier, Jacobs, and Mumford's visions. For Sennett, the core ethical problem in any city is dealing with others; moving from this ethical issue, and with the aim to facilitate a city that is porous, incomplete and multiple, he suggests ways to remake the *cité* by focusing on urban design, emphasizing the presence of permeable open spaces and variegated type-forms, creating co-development practices by experts and public.

Shape and size of the city matter (Batty, 2014; West, 2017). Current statistics[1] show that by 2030 the world's population is projected to be 8.5 billion, increasing to 9.7 billion by 2050 and 11.2 billion by 2100; moreover, if 1950 only 30% of the population lived in cities, in 2050 this percentage is expected to grow to 70% (already nowadays more than half of the world lives in cities). New cities will necessarily emerge and become centers of the new civilizations, life, and knowledge for centuries. These trends will challenge cites' services and infrastructures in terms of scalability, environmental impact, security as they are supposed to adapt in order to support this population growth. New research can be carried out by conceptualizing cities as complex adaptive systems (West, 2017); but differently from companies and human beings, they (almost) never die and are remarkably resilient; their urban metabolism – which is the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy and elimination of waste (Kennedy et al., 2007, 2011) – is what needs to be investigated since it provides with the basis to develop laws and indicators aimed to disentangle the dynamics of the visible city (material and tangible components like roads, buildings, etc.) and the invisible city (immaterial and intangible components like social networks and information). Central to this debate become the *suburbs-city centers' dynamics*. If it is true that the majority of people will live in cities, it seems (from current trends) that many of them populate the suburbs. Smart cities can be the way to rethink the role of suburbs as a bridge to connect the city with the others and become the center of interconnections with new communities. This can give a new role to small cities, rural areas and villages in that they can potentially benefit from the Internet revolution and repopulate: in fact, smart working practices take place to rethink one's lifestyle and promote factors such as sociability and well-being, which are increasingly difficult to maintain in large cities (or megalopolises). Jean-Jacques Rousseau had already thought of this when he stressed the need for people to distance from the cities and return to the villages.

[1] https://www.un.org/development/desa/en/news/population/world-population-prospects-2017.html.

7. Conclusions

In this introduction to the special issue of the Technological Forecasting and Social Change "Understanding Smart Cities: Innovation Ecosystems, Technological Advancements, and Societal Challenges" we discussed the broader theme of Smart Cities and attempted to reframe associated topics and practices in prior work. Next, we introduced the papers in the special issue and linked them to the proposed hybrid framework. Finally, we offered a research agenda which points out the urgent need to develop a *science of smart cities*, in which criticalities and tensions (Almirall et al., 2016), contrasting views (Greenfield, 2013), strategic planning and wise urban policies (Sennett, 2018), through a balanced adoption of qualitative and quantitative approaches, coexist and further stimulate a constructive and critical debate. Thus, we hope this special issue will inspire future work on the nature and challenges of current and future smart cities initiatives.

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