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SPECIAL FEATURE: ORIGINAL ARTICLE

People, Technology and Governance for Sustainability: The Contribution of Systems and Cyber-systemic Thinking

Crossing technology and sustainability in cities' development

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Abstract
This paper deals with sustainability in cities and the role technology plays in furthering sustainable results. Recently, many interventions have been implemented in cities to propose paths and models promoting the sustainability of cities from an overall perspective. Technologies are favouring the achievement of aims recalling the three spheres of sustainability as proposed by Arcadis (2017), namely "planet", "profit", and "people". The ties between technology and the three spheres are investigated through a content analysis of reports issued by the 10 cities with the most significant advances in terms of becoming sustainable cities, as indicated in the Arcadis Report 2016. The results highlight technology as an element crossing sustainability, as processes and models in cities management and service provisions to citizens are significantly changing. New tools are innovating the processes addressing environmental issues, thus leading to cost efficiency and better economic conditions. Parallel to this, new models for city management and the provision of public services are addressing the need for a better quality of life for citizens and cities' other stakeholders. Technology itself is thought of as sustainable because it should lead to efficiency and being efficient itself. A qualitative cluster analysis and a focus on excerpts from reports are proposed to highlight the ties between technologies and the elements representing key issues in managing and leading a city towards more sustainable conditions.

Keywords Sustainable cities · Technology · Cities · People · Sustainability

Introduction

Improving citizens' quality of life, identifying innovative strategies and policies, and promoting sustainable and integrated urban development are key issues in cities all over the world (European Commission 2017), included in one of the 17 goals identified in the 2030 Agenda for Sustainable Development (UN 2015). In detail, the purpose of the goal 11—i.e., make cities inclusive, safe, resilient, and sustainable—concerns the increase of social and economic opportunities for people in respect of natural resources. In this scenario, new technologies are considered fundamental tools for managing the demanding pathway towards sustainable cities and creating innovative public services for citizens (Bifulco et al. 2016).

The identification of the recurring features in academic contributions leads to the emergence of sustainability as one of the main aims of city managers (Enquist et al. 2007). In addition to elements linked to social, economic, and environmental development (Rogers and Ryan 2001), the sustainability-oriented initiatives in sustainable cities (Tregua et al. 2015) require the participation of citizens and their engagement for the co-creation of services (Barile et al. 2015). Indeed, all the actors in urban contexts (i.e., citizens, universities, firms, local administrations, etc.) can be considered—together with technologies—means for the spreading of new knowledge and information, as well as for the development of innovative public services. Nevertheless, the importance of technologies in facilitating sustainable initiatives and encouraging actors' participation in urban life, especially citizens, is considered a research perspective that needs to be deeply investigated (Angelidou and Psaltoglou

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2017), also in selecting the most appropriate indicators to measure sustainability (Hák et al. 2016).

To answer to these calls for research and reach the main aims of understanding how cities are developing sustainability-based initiatives and how technologies are used to achieve the targeted sustainable goals, this paper is organized as follows. The literature review is conducted through an analysis of studies concerning urban contexts as complex systems with a focus on the elements characterising sustainable development in cities; moreover, the review identifies the main features of technologies in improving the quality of life for people in cities and the two roles that technological tools—often referred to as smart technologies—can play in supporting the achievement of sustainable goals. The key issues and gaps identified in the literature are used as a basis for depicting the aim of this paper and the presentation of the adopted methodology. The latter is a content analysis (Leech and Onwuegbuzie 2011; Krippendorff 2012; Stemler 2015)—based on such primary tools as proximity analysis and qualitative cluster analysis through the software NVivo—of the first ten cities of the ranking "Sustainable Cities Index 2016", recently released by Arcadis (2017). The results of the analysis are then presented and discussed to underline how technologies and the three main features of sustainable development are strictly related in urban contexts aiming for sustainability. Finally, the limitations of the paper and the starting points for further research are presented, giving way to future studies aiming at a better and deeper understanding of how cities are moving towards more sustainable conditions.

Theoretical review

Sustainable cities

In recent years, more scholars are focusing their attention on the configuration of urban contexts (Anthopoulos and Vakali 2012; Tregua et al. 2014; Werner and Kelcey 2017). A scan of literature reveals that many contributions describe modern cities as complex systems aiming to achieve sustainable development through the support of ICTs; no city is an island (Barroso 2013). Indeed, cities are often considered "systems of systems" (Egger 2006; Nam and Pardo 2011; Harrison and Donnelly 2011) because a constant resource exchange is needed to survive and pursue sustainability (Newman and Kenworthy 1999).

An example has been provided by Egger (2006), who states that "The planet may be considered in terms of a series of interdependent biological and socio-economic systems that have both spatial and temporal relationships. The complexity of these systems should not discourage attempts to understand them and create a more sustainable interaction by humanity with them. The dominance of people and their increasing urbanization requires that the city system be given particular attention in achieving sustainability".

In 1999, Newman and Kenworthy had compared the city to a biological system introducing the "Extended Metabolism Model"; according to them, city's survival is based on a balance of resources' input and output, as well as the ability of citizens to preserve resources and manage unexpected events (Brundtland 1987; Atkinson et al. 2014; Redclift 2005). The feature of reacting to changing face to external conditions, even when the unpredictable takes place, has been referred to by scholars dealing with cities management (Surjan and Shaw 2008).

The attention paid to the new configurations of the urban context led to the introduction of different labels aiming to define new frameworks. The most frequently discussed label is "smart city", namely, an urban context based on a set of elements useful for improving citizens' quality of life through a sustainable approach (Nam and Pardo 2011; Chourabi et al. 2012; Zubizarreta et al. 2015).

As time passed, the attention paid to sustainable development required the introduction of a new definition, namely the Sustainable City. This new configuration was not considered an evolution of previous configurations, but rather a new approach based on the three elements on which the sustainable approach is based.

A relevant contribution to defining a sustainable city has been offered by sources other than those in the academic literature (Pickett et al. 2013; Guzmán et al. 2017); indeed, Arcadis, a Dutch organization dealing with urban planning projects all over the world, favoured a new definition and a more detailed approach to what a sustainable city is. Arcadis (2017) provided a set of indicators to monitor the evolution of the cities adopting a path towards the sustainable city, even setting up a rating. Indicators have been proposed by Arcadis and collected in three different categories identified according to areas of sustainability approach, namely, social development, environmental development, and economic development. Arcadis named the three groups "People", "Planet", and "Profit" describing the efforts performed to achieve, respectively, social improvements, better environmental conditions, and improved economic performance. The "Sustainable Cities Index" issued by Arcadis presents several indicators in the three categories; the area named as "People" is based on demographics, work-life balance, affordability, education, crime, income equality, and health; when evaluating the environmental sphere, namely the "Planet" area, the indicators used are environmental risks, air pollution, drinking water and sanitation, energy, greenhouse gas emissions, green space, and waste management; the evaluation of "Profit" is depending on transport infrastructure, tourism, economic development, connectivity, ease of doing business, and employment. Arcadis stressed

the need to achieve a balanced development, so the three groups are not just a sum of different goals, but they represent the intertwined pillars of a sustainable future.

In summary, while in scholars' contributions the topic of sustainable cities has been mainly spreading in the last few years (Fan and Qi 2010; Tregua et al. 2015; Jenks 2017), some definitions had already been proposed in the nineties, such as the one provided by the United Nations Centre for Human Settlements (UNCHS) in 1991, which considered a sustainable city to be a context "where achievements in social, economic and physical development are made to last".

A relevant contribution anticipating the main research trend on sustainable cities had been offered by Satterthwaite (1997), who stated that "Sustainable Cities should meet their 'inhabitants' development needs without imposing unsustainable demands on local or global natural resources and systems". Similarly Rogers (1998) elaborated a "list of key attributes of such a city to include equitable access to basic services, beauty in its art and architecture, creativity to optimise human potential, resource efficiency and minimal ecological impact, ease of contact, mobility, integrated and compact communities and diversity".

This last definition appears to be very close to the current approach, as it considers the sustainable development of the city, including the preservation of resources and the improvement of citizens' quality of life, to be the final goal (Brundtland 1987; Robert et al. 2005; Barile et al. 2012; Hák et al. 2016). One of the main challenges in developing a city is the balanced development of all its areas (Vanolo 2014), since the interventions are often performed in only some parts of the city to counteract specific problems or to focus on particular issues. The approach proposed by Arcadis is aligned to the need of a balanced development when highlighting cities performance as better addressing goals related to planet and profit, but failing in meeting people needs. Anyway, the achievement of a balanced development is presented as a difficult task, due to the conflicting elements among the three Ps, namely "People", "Planet", and "Profit".

Technology in sustainable cities

As stated in the previous paragraph, the evolution of technological tools led to the involvement of new technologies in almost all aspects of everyday life with the aim of improving people's quality of life (Caragliu et al. 2011; Bifulco et al. 2016).

Following the new discoveries about environmental damages, scholars paid even more attention to the impacts of human activities and sustainable development as the main aim for people and local administrations to pursue. As a consequence, recent studies focused on the need to measure the impact of cities' interventions on the environment, with particular reference to the ecological footprint (Chapman et al. 2017).

The sustainable development of urban areas is considered strictly connected to technologies. An analysis of literature contributions reveals the necessity of taking on a new holistic system for integrated data acquisition, querying, and mining that can be realized through the development of common open platforms and ubiquitous ICT infrastructures (Lombardi et al. 2012; Angelidou and Psaltoglou 2017). Indeed, nowadays new technologies are considered an unavoidable element of managing cities (Camagni et al. 1998; Ishida and Isbister 2000), as well as a key tool to achieve sustainable development and create a more open and innovative urban context through the participation of several actors interacting thanks to ICT tools—namely, "mobile devices (e.g. smart phones), the semantic web, cloud computing, and the Internet of Things (IoT) promoting real world user interfaces" (Schaffers et al. 2011, p 434).

The pivotal role new technologies play in the evolution of urban contexts can be identified in the advances that have been widely exploited thanks to the diffusion of mobile devices, which allow people to participate in (Kirwan 2015) and contribute to their urban and metropolitan environments.

It is possible to deduce that people's participation in the evolution of urban areas is strictly related to and facilitated by intelligent instruments (Bulu 2014) through a co-creation approach (Kirwan 2015; Grunewald et al. 2017). From a long-term perspective, the function of new technologies is to reduce the environmental impact and improve the economic effects of human activities.

Thus, the role new technologies play can be observed from two different but complementary perspectives: first as they can be considered an unavoidable support for activities to be deployed and second as a means to favour resource integration and the participation of various stakeholders through platforms to preserve available resources using a sustainable approach.

The first one relates to short-term activities based on the participation of all actors involved in the urban life who, thanks to the support of technology, can immediately act in city management and governance (Bingham et al. 2005; Schaffers et al. 2011; Liao et al. 2017).

The second refers to the long-term objectives of city managers, namely, to reduce the local and global impacts produced by human activities. According to Camagni et al. (1998), the primary long-term aim of technology tools employed in urban areas management is to reduce the environmental impact of human activities through more environmentally friendly initiatives (i.e., the reduction of pollution produced by means of transport or heating systems). Particularly, technologies—especially so-called smart ones—are used in the development of sustainable initiatives

to save energy due to the interaction of different actors and the involvement of various resources (Chourabi et al. 2012).

In any event, as it emerges from the analysis of literature contributions, it is impossible to reduce the role of new technologies, considering them simply tools to contain environmental impacts. Their relevance is first related to the opportunity to involve citizens in city governance so as to accomplish sustainable development, even if, currently, tangible evidence that shows the relevance of citizens' participation in city governance through technology devices is limited (Schaffers et al. 2011; Komninos 2013; Jenks 2017).

Aim and methodology

Starting from our literature review, we highlighted the need to better understand how technology is supporting the achievement of sustainability in cities just as it is transforming cities in sustainable ones. To achieve the aforementioned aim, the authors have paid attention to evidence all over the world provided by the "Sustainable Cities Index 2016", as proposed by Arcadis (2017), as it is the most updated among the available rankings and is based on a combination of relevant sources, such as the World Bank, World Health Organization, United Nations, and so on. Additionally, the data are unbiased because they are not provided by city or local agencies themselves, so the confidence and quality of the proposed information is grounded.

As a second step, the evidence provided by local actors has been combined to propose a more unified approach to sustainable cities in which the three elements of the sustainable development—namely, planet, profit, and people—can represent a useful roadmap for proposing a more complete understanding of how cities are moving towards sustainable conditions.

In detail, the empirical research proposed in the following pages focuses on the first ten cities of the ranking, considered the most representative of the study performed by Arcadis: Frankfurt, Hamburg, London, Munich, Prague, Seoul, Singapore, Stockholm, Vienna, and Zurich. The following table (Table 1) shows a comparison among the different rankings of the selected cities, namely the overall index and the results reached by the cities in each of the three elements of planet, profit, and people.

The selection was conducted using a web search engine, namely, Google.com (Jacobs et al. 2014), and for each city the first three documents reported have been collected—30 reports from 13 to 124 pages long, published between 2014 and 2016—to perform a content analysis useful for identifying the key elements of sustainable city processes.

In the following table (Table 2) authors listed the most relevant document for each city.

Table 1 Comparison of different rankings proposed by Arcadis. Authors' elaboration from Arcadis (2017)

Cities	Ranking			
	Overall	Planet	Profit	People
Zurich	1	1	5	27
Singapore	2	12	1	48
Stockholm	3	2	10	14
Vienna	4	4	14	4
London	5	9	3	37
Frankfurt	6	5	23	16
Seoul	7	26	18	1
Hamburg	8	10	25	3
Prague	9	31	7	6
Munich	10	24	11	8

The content of documents provided relevant data because they all contained information about strategies, goals, and actors involved in city projects based on the sustainable approach. The analysis has been performed using the software NVivo—version 11 for Windows—(Leech and Onwuegbuzie 2011; Krippendorff 2012; Stemler 2015) because it is considered one of the most suitable tools for performing this kind of analysis (Houghton et al. 2015; Bifulco et al. 2016). Moreover, the software provides the opportunity to perform different levels of analysis and to combine results to classify the information obtained and observe among them linkages that can be presented in statistical indices and graphs, which themselves are useful in considering the relevance of the results. More in detail, word frequencies, stemmed categorizing, proximity analysis, and qualitative cluster analysis are the key tools this paper uses to grasp meaning from the reports and depict the contribution of technology in furthering sustainability into planet, profit, and people—the three pillars of a sustainable city.

Findings

The analyses of documents led to considerations of three main elements, namely, the sources used, the perspective towards sustainability in cities, and the role played by technology. Moreover, additional insights depend on the chance to combine the main topics and describe the relationships they have with one another. Thus, the findings will be proposed in the next lines by following this structure: an overview of documents, the framing of sustainability, the description of technology-based interventions, and the links between technology and the main pillars depicting sustainability in cities; the contribution of technology in achieving sustainability-oriented results will be analysed as a crossing

Table 2 Most relevant document for each city. Authors' elaboration

Cities	Documents	Issuer	Year
Zurich	Sustainability monitoring in the City of Zurich summary 2015	City of Zurich	2015
Singapore	Our home, our environment, our future. Sustainable Singapore Blueprint (SSB) 2015	Ministry of the Environment and Water Resources, Ministry of National Development	2014
Stockholm	Sustainable cities—Energy efficiency Renovation and its Economy	City of Stockholm, Environment and Health administration	2015
Vienna	Urban Mobility Plan Vienna	City of Vienna	2015
London	London Sustainable Drainage Action Plan. Draft for public consultation	Greater London Authority City Hall	2015
Frankfurt	UN Global Compact Communication on Progress Messe Frankfurt 2015/2016	Messe Frankfurt GmbH	2016
Seoul	ICLEI Seoul Strategic Plan 2015–2021. Building a World of Local Actions for a Sustainable Urban Future	ICLEI, Local Governments for Sustainability	2015
Hamburg	Hamburg–European Green Capital: 5 Years On. The City takes it further	Ministry of Environment and Energy	2016
Prague	City of the Future. City lab Prague–executive summary	Fraunhofer Institute for Industrial Engineering	2016
Munich	Munich Transport Corporation (MVG). Sustainability Report 2014/2015	Münchner Verkehrsgesellschaft	2016

element favouring the development in each of the three areas.

Overview of data analysis

The first results of the documents used in the content analysis highlighted a low rate of correlation among the sources used. This result is useful for considering the documents as not being based on the same content and as independent of one another. This evidence empowers the results to be achieved through the analyses, since the documents issued by the same city are not just a re-edition of previous contents. Indeed, the correlation rate is between 0.04 and 0.29 on a range from 0 to + 1 based on Jaccard's coefficient. The average correlation among documents is only 0.14, stressing the independence of the sources taken into account and making the perspective of our analyses unbiased and wide.

We performed word frequency by discarding the first two words - "city" and "sustainable" - which is an obvious result; the top 50 evidences of the word frequency have received attention after the discarding of some words (such as articles, adjectives, numbers, and so on) useless for obtaining insights from the content analysis; these kinds of entries are added to the "stop list", so they will not affect the next steps of this investigation. As mentioned previously, services (transport, energy, mobility, other utilities such as water, infrastructure, and parking), issues (green, traffic, planning, efficiency, bike, car, projects, climate), and features of cities (building, people, management) are the categories summarizing most of the words used in the considered reports. In any event, this focus on the most frequent words is useful only for framing the analysis to be done in the next step, as some of the elements should be framed to grasp more meanings and contextualize them in relation to other topics. The attention paid to specific meanings led us to keep the level of analysis on single words instead of on stemmed words, as the achievable results combine topics not actually considered synonyms.

Framing sustainability

A specific query has been run to better depict sustainability in the collected reports; in each report, the topic of sustainability is considered 62 times on average, with a maximum achieved by Singapore, citing it 268 times in a single report. Apart from the number of occurrences, the coverage is quite significant, as the word sustainability represents 0.68% of the average content of each document, with a maximum of 1.70% in one of the reports issued by Munich.

Sustainability is considered mainly as the state to be achieved by a city and its neighbourhood; more in detail, it is considered in different ways: in relation to the elements of a city, to the conditions of living in them, and to the services provided to local actors.

When relating sustainability to services provided in cities, transport is the most recurring topic. All cities considered in the analysis stated that they have paid significant attention to turning their transport systems into sustainable ones. Several comparative analyses are performed by cities to benchmark past results and best practices emerging from other contexts. Moreover, some indicators are identified to favour the measurement of the advances achieved towards a sustainable transport system.

In addition to transport, building and architecture are two areas greatly affected by the challenge of sustainability. Reports highlighted a common relationship to time as the element projecting sustainable buildings in the future. The centrality of sustainability with respect to the issue of architecture is even more prominent when one references the need to achieve the certification of ecological sustainability in respecting building standards, construction requirements, and measures to constantly measure the achievement of this aim. These elements are mostly common in Central European cities, and their reports offer great technical insight into building and measuring sustainability.

Energy and climate are two additional areas affected by the struggle for sustainability. They are often proposed together in reports because they mutually affect one another. More in detail, cities should aim to use renewable energies that do not affect climate conditions; sustainability is meant to be a time-based aim because both current services and those of the future are directly affected by these environmentally friendly sources of energy.

Approaches to sustainability are proposed by cities when mentioning a general optimization of processes; the need to propose solutions and package them is thought of in a more sustainable way, while the planning and development of projects is oriented to make cities more sustainable. These features can be highlighted in all reports. The core uses of sustainability are two, namely, the main characteristic of cities' goals and the need for local actors to be committed to sustainability.

Additionally, we analysed sustainability by considering the three Ps proposed by Arcadis in its report, namely "planet", "profit", and "people". After considering the interventions performed with reference to each of the three Ps, we investigated the contribution technology gave to the achievement of sustainable goals.

We performed the analysis with reference to both single items and categories of stemmed words to grasp more meanings. A focus on the three areas of sustainability emerged as useful in stressing the attention cities pay to sustainability in the three different spheres. Quite surprisingly (in comparison to the overall results with respect to sustainability), "people" is the area most commonly taken into account when considering the path towards sustainability, while "planet" and "profit" are slightly less relevant, though still crucial, in line with the general description of sustainability provided previously. "Planet" considered primarily the call to action to take care of the environment in terms of both natural resources and climate; moreover, the use of the word "planet" is related to the need to create a commitment to the aim to be achieved and to measure impacts on global conditions. "People" is the way to stress the role of all actors of a city, both in supporting the processes to achieve sustainability and in benefiting from the better conditions created through sustainability-oriented projects. Cities launching or managing projects on sustainability are stressing the fact that they are people-oriented and that attention must be paid to people's needs when identifying what to do with respect to sustainability; this is even mirroring the call for interventions launched by Arcadis in the past to counterbalance the missing attention to "people" when compared to "profit" and "planet". "Profit" is thought of as the way to represent the long-term perspective on sustainability, as it is mirroring the effects to be achieved after deploying actions oriented towards sustainability. Indeed, cities are stressing the need to invest large amounts of money in furthering sustainability, though economic and financial aspects are expected as an additional—even if not necessarily secondary—result due to its appearing in the future. More in detail, the results of applying sustainability are thought of in the short term as the direct consequence of efficiency (e.g., saving costs), though most of the positive economic and financial performances are represented by the outcomes of projects after their deployment. From a general perspective, it is possible to describe the achievement of the three sustainability-oriented goals through an analysis of the support offered by technology in stressing both the three Ps and the balance among them.

Technology-based interventions

First, we considered technology under different labels, such as technology(-ies), information and communication technologies, digital tools, and so on. The use of the word "technology"—or its plural form—is common in the report of all cities, while other ways to define technological instruments are used in only a few cases; as a consequence, a proximity analysis was performed to find all the cases in which the word "technology" was used and to grasp meanings from the context in which the word was used. Conversely, we discarded the results from the stemmed word with the root "tech" because too many elements with different meanings were embedded.

The table below (Table 3) represents the words most commonly used together with "technology" as the core result of the proximity analysis.

The approach towards innovation, the care of the environment, and the different services benefiting from the implementation of new technologies are the most common results. Such an analysis highlights the frequency of topics used together with "technology", but no insights are offered about how relevant they are. To provide additional insights and meaningfulness to our analysis, we used this evidence to move towards a focus on the most relevant connections between "technology" and the other issues reported in the documents we chose. Consequently, the following graph (Fig. 1) summarizes the results emerging

Table 3 Qualitative cluster analysis on proximity analysis based on technology. Authors' elaboration from NVivo

Word	Count	Weighted Percentage (%)	Word	Count	Weighted Percentage (%)
Technology	532	9.96	Transport	22	0.41
Innovative	58	1.09	Institute	20	0.37
New	54	1.01	University	20	0.37
Energy	52	0.97	Communication	18	0.34
Development	50	0.94	Heat	18	0.34
Solutions	44	0.82	Mobile	18	0.34
Smart	34	0.64	Progress	18	0.34
Sustainable	34	0.64	Urban	18	0.34
Efficient	28	0.52	Test	18	0.34
Information	28	0.52	Cities	16	0.30
Green	26	0.49	Electric	16	0.30
Environmental	24	0.45	Environment	16	0.30
Industry	24	0.45	Infrastructure	16	0.30
Vehicle	24	0.45	Solar	16	0.30
Building	22	0.41	Water	16	0.30

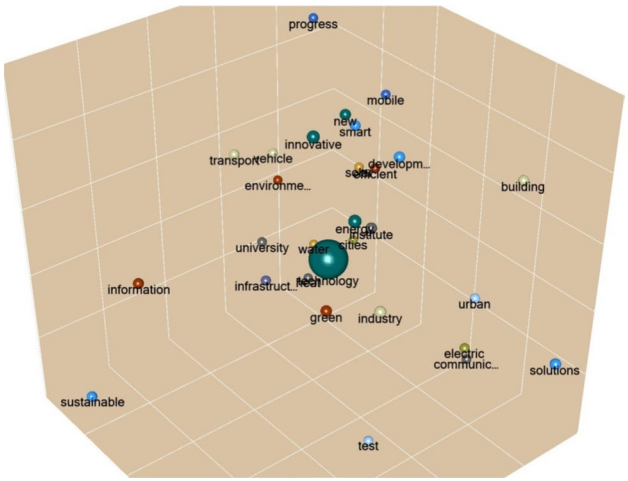

Fig. 1 Qualitative cluster analysis of proximity analysis based on technology. Authors' elaboration through NVivo

from the proximity analysis and the elaboration performed on it to achieve a qualitative cluster analysis. This latter is useful for achieving a better understanding of the linkages among the topics and especially between "technology" and each of the other topics.

The reports deal with technology in different ways. The most relevant ones are related to the environment (e.g., water, green), services (e.g., infrastructure, energy, communication), and actors (e.g., universities, industries, institutes). The topics represented in the graph above are all frequently related to technology, and all these linkages are highly significant because we set a Jaccard's coefficient higher than 0.9. The topics represented by bigger spheres are the most frequently occurring, while the closer a topic is to "technology", the stronger its correlation in the reports.

More in detail, technology is proposed mainly as a solution to provide services to cities in new ways because processes are innovated through new tools. Consequently, services are provided through new solutions inspired by human needs—both traditional and emerging—but are shaped by technologies and the new features they offer. The technologies are defined as both the outcome of innovation processes and the trigger of innovation because they are changing traditional ways of providing services. From an overall perspective, the innovations modify even the way in which actors operate in cities, as models for planning, deploying, and controlling processes are being proposed in a technology-based way.

The technologies considered by cities address new ways of service provision, with particular reference to energy and transport. The link between technology and energy is two-fold and mutual because, on the one hand, technology is thought of as energy-efficient while, on the other hand, it should lead to higher efficiency in using energy. As it regards transport, technologies are basically thought of as a way to improve service provision through the availability of real-time information, the identifying of better routes, and the integration of different means of transport, both public and private. Additionally, technologies are meant to modify some means of transport, leading to better performance from an environmental perspective. Moreover, other services provided to citizens are featured by technologies, as health care and others are directly linked to better living conditions. Each city reported specific ways to answer local needs in a new manner led by new technologies and to use technologies as a tool promoting the preservation of natural resources.

This latter element stresses more strongly the link between technology and sustainability.

Finally, technologies are considered crucial because they involve people in several ways. First, they are smart and mobile, so they allow people to participate in new processes through their own devices and in real time. People participation is meant as service provision and information sharing, such as when an actor is required to integrate resources with someone else to accomplish a condition related to a public service, as is the case for transport (e.g., combining means of transport), energies (e.g., sharing data about consumption to get insights on improving usage), and living (e.g., creating profiles on a digital platform to get information about job offers and public services from local administrations). This result is mirroring the social role played by information, since people are empowered and involved in interacting among them and with the public services providers. Furthermore, the way in which some cities have proposed new technologies depends on people because novel tools have been tested in Living Labs, so citizens and other actors shape a test-bedding context useful before launching new technologies. Similarly, the proximity analysis highlighted some specific actors linked to "technology", such as universities, research institutes, companies supporting sustainability-oriented projects or providing services in cities, and political entities such as ministries or local agencies.

Linking technology and sustainability

To highlight the links between technology and the elements shaping the perspective on sustainability proposed by Arcadis (namely, planet, profit, and people), we crossed the evidence acquired for each of the topics presented above. Word frequencies, proximity analyses, the ties among them, and a qualitative cluster analysis have been combined through the software we chose; consequently, some excerpts will be proposed in the following lines to show the linkages that emerged.

First, technologies in reports are meant to be sustainable instruments themselves and drivers for further sustainability in cities and the services they provide. The tie between technology and sustainability is stressed even more when advances in technologies are presented as "sustainability-focused", "green", or "clean", namely, in ways highlighting the need for a new approach towards applying technologies in cities for services.

When crossing "planet" with "technology", the evidence provided details about how technologies support environmentally friendly interventions, based mainly on higher efficiency, either in using natural resources or in counteracting waste. A summarizing statement is suggested in a report about Seoul when proposing an "appropriately innovative use of techniques, technologies and natural resources". More in detail, a report about Frankfurt stated that energy has "been provided with the latest technology" in the buildings in some areas of the city to decrease consumption and pollution. Similarly, local agencies in Hamburg decided to invest "in energy rehabilitation and technology in owned buildings" to act in a more efficient way. Public-owned buildings were chosen as the test-bed.

When considering "profit" and "technology" cost efficiency together, additional revenues from new services, changes in the results of some traditional services, and financing from supranational institutions are the key issues stressed and aimed at in sustainability-oriented interventions. Cost efficiency is proposed as being intertwined with environmentally oriented interventions, as proposed in a report about Stockholm, especially when comparing "site-built and prefabricated technology for insulation" or when measuring the consequences of "the latest technology for several climate friendly measures". The changing conditions for public services are stressed in a report about Singapore, with the technologies already applied by the city government evaluated as crucial "to keep up with technological improvements and changing market conditions".

Additionally, Singapore underlined the opportunity sustainability offered with respect to plans to apply for a "grant for energy efficient technologies" that favour eco-friendly projects and the innovative design of processes, with particular reference to transport services.

When combining "people" and "technology", the focus is on the ways in which technologies can favour better living conditions, not only as a consequence of a better environment, but in the form of wider attention paid to quality of life. An example is offered by a report about London, which stated that partnerships have been created between the city and key players in the high-tech industry to better discover "the potential of technology to increase the well-being". Moreover, another report about London identified the already-running interventions favouring sustainability in daily activities, as the local government involved a "standard supermarket by incorporating new technologies and design innovations". Finally, technologies are the way to involve all the stakeholders of a city in furthering sustainability, as "smart technologies combined with smartphone-based services" can favour the participation of a plethora of actors in new processes, as proposed in the report about Prague.

Discussion

The results of the content analysis allow us to determine which is the most-used depiction of sustainability by cities implementing activities oriented towards social, economic, and environmental development according to sustainable development goals (Brundtland 1987; Robert et al. 2005;

Barile et al. 2012; Hák et al. 2016). Most of the cities consider sustainable those initiatives for a multi-modal and user-friendly transport system, as well as for the construction of energy-efficiency buildings and the use of renewable energies. Looking at these results in the lens of the three features of sustainability, we can state that "planet" is the main aim cities are trying to reach through their initiatives. Moreover, to deploy these initiatives, all the cities are using technologies that emerged as triggers of innovation in city services, as recently stressed by Angelidou and Psaltoglou (2017).

Anyway, apart from the initiatives linked to the environment, authors observed that technological tools started to be involved even in the other two spheres, namely "profit" and "people". In detail, as it concerns the former, most of sustainability projects considering smart technologies refers to the enhancement and renovation of the infrastructures, aiming at improving citizens' quality of life and favour tourism activities. As it concern the latter, new technologies represent a way to engage citizens in the city governance, giving them the opportunity to acquire a pivotal role in the local development.

As discussed above, use of smart technologies is strongly related to the "planet" feature of sustainability, as they help reach higher efficiency in energy consumption, providing real-time information about and suggestions for public transport and traffic, and preserving natural resources inside urban contexts (Nam and Pardo 2011; Schaffers et al. 2011).

To expand the previous perspectives (Angelidou and Psaltoglou 2017), authors highlighted that the results concerning technologies help widen the scenario of sustainability in cities as the importance of "people" emerges—the social development in cities. As previously stated, this feature mainly concerns the increasing participation of urban stakeholders, especially citizens, in urban life due to the creation of test-bedding contexts such as Living Labs, where firms, public actors, and citizens collaborate to develop the most suitable innovative services to improve quality of life (Caragliu et al. 2011; Bifulco et al. 2016); thus, Living Labs and all the interventions aimed at involving people in sustainable development can be considered as direct ways of support proposed by central institutions when shaping their policies towards sustainability.

As emerges from the results, attention is paid especially to the environmental aspects of sustainability because sustainable cities are considered mainly as an urban context aiming to preserve local resources. Indeed, the sustainable approach has been introduced as a tool to avoid environmental disaster or the depletion of natural heritage (Brundtland 1987; Redclift 2005; Atkinson et al. 2014).

The observed link between technology and sustainability opens a perspective on the "profit" feature that does not appear to be a priority in cities promoting sustainable initiatives, but it emerges in relation to the achievement of cost efficiency and issues of financial resources to sustain initiatives, often with funding provided by national or supranational agencies. Less attention on economic development can be explained with the focus of public actors on short-term results related to their mandate rather than an insufficient importance placed on long-term sustainability goals.

Moreover, the results show that technologies are usually referred to as "smart technologies" (Chourabi et al. 2012) and allow for the delineation of a link between technologies as the intelligent elements in urban contexts—smart cities—and the social, environmental, and economic development in the same urban area—sustainable cities (Newman and Kenworthy 1999; Schaffers et al. 2011). The relation between and overlap in the two concepts confirms what appears in the literature review (Bulu 2014; Tregua et al. 2015), allowing for the expansion of the concept of sustainable cities as based on the three elements of sustainable development gathered together through the use of technologies bringing innovation to urban services.

Conclusions and further research

In summary, the role of technology in supporting different areas permeates a sustainable approach towards cities, which has emerged with reference to "planet", "people", and "profit". Sustainable development should be regarded from a spatial perspective, as splintering urbanism (Vanolo 2014) should be avoided so as not to create under-developed areas in a city, especially peripheral ones.

Moreover, according to the emerging importance of social development (Jenks 2017)—the P of "people"—the planning and deployment of sustainability-oriented goals are increasingly characterised by the involvement of different actors bringing their own resources (Barile et al. 2015), favouring the set necessary to perform activities in innovative ways and support the achievement of the fixed goals (Angelidou and Psaltoglou 2017).

The participation of people and all civic society can be further analysed in future research using the Quadruple Helix Model, with its concepts of co-evolution of economy and society and citizens as co-creators of a more sustainable urban context. Moreover, the Quintuple Helix Model can be even more helpful because it integrates the natural environment, allowing for the analysis of the three elements of sustainable development: people, planet, and profit.

This paper is based on the results of a content analysis of reports and official documents concerning the top ten sustainable cities (Arcadis 2017) and available on the web. These features represent the main limitations of this research since we used only one of the different rankings available on sustainable cities and we collected secondary data. Further research can enlarge both the perspective (through the

analysis of different rankings) and the data collected via direct interviews of city managers involved in sustainability-oriented initiatives or via a mail survey on the use of technologies in urban activities concerning people, planet, or profit.

The investigation can be performed again using updated rankings or new documents provided by local administrations or private actors. Furthermore, the analysis can be repeated by launching again the research on Google.com to verify if the indexing of the documents is changed; a new indexing could induce authors to repeat the data collection to consider publications emerged as more relevant.

References

Angelidou M, Psaltoglou A (2017) An empirical investigation of social innovation initiatives for sustainable urban development. Sustain Cities Soc 33:113–125. https://doi.org/10.1016/j.scs.2017.05.016

Anthopoulos LG, Vakali A (2012) Urban planning and smart cities: Interrelations and reciprocities. In: Álvarez F et al (eds) The future internet assembly. Springer, Berlin, pp 178–189. https://doi.org/10.1007/978-3-642-30241-1_416

Arcadis (2017) Sustainable cities index 2016. https://www.arcadis.com/en/global/our-perspectives/sustainable-cities-index-2016/. Accessed 24 July 2017

Atkinson G, Dietz S, Neumayer E, Agarwala M (2014) Handbook of sustainable development. Edward Elgar Publishing, Chelthenham

Barile S, Saviano M, Polese F, Di Nauta P (2012) Reflections on service systems boundaries: a viable systems perspective: the case of the London Borough of Sutton. Eur Manag J 30(5):451–465. https://doi.org/10.1016/j.emj.2012.05.004

Barile S, Saviano M, Simone C (2015) Service economy, knowledge, and the need for T-shaped innovators. World Wide Web 18(4):1177–1197. https://doi.org/10.1007/s11280-014-0305-1

Barroso JM (2013) No city is an island, Covenant of Mayors ceremony, Brussels, 24 June 2013. http://europa.eu/rapid/press-release_SPEECH-13-566_en.htm

Bifulco F, Tregua M, Amitrano CC, D'Auria A (2016) ICT and sustainability in smart cities management. Int J Public Sect Manag 29(2):132–147. https://doi.org/10.1108/IJPSM-07-2015-0132

Bingham LB, Nabatchi T, O'Leary R (2005) The new governance: Practices and processes for stakeholder and citizen participation in the work of government. Public admin rev 65(5):547–558. https://doi.org/10.1111/j.1540-6210.2005.00482.x

Brundtland GH (1987) Report of the World Commission on environment and development: "our common future". United Nations

Bulu M (2014) Upgrading a city via technology. Technol Forecast Soc 89:63–67. https://doi.org/10.1016/j.techfore.2013.12.009

Camagni R, Capello R, Nijkamp P (1998) Towards sustainable city policy: an economy-environment technology nexus. Ecol econ 24(1):103–118. https://doi.org/10.1016/S0921-8009(97)00032-3

Caragliu A, Del Bo C, Nijkamp P (2011) Smart cities in Europe. J Urban Technol 18(2):65–82. https://doi.org/10.1080/10630732.2011.601117

Chapman M, La Valle A, Furey G, Chan KM (2017) Sustainability beyond city limits: can greener beef lighten a city's Ecological Footprint? Sustain Sci 12(4):597–610. https://doi.org/10.1007/s11625-017-0423-7

Chourabi H, Nam T, Walker S, Gil-Garcia JR, Mellouli S, Nahon K, Scholl HJ (2012) Understanding smart cities: an integrative framework. In: 45th Hawaii International Conference on System Science (HICSS), IEEE, pp 2289–2297

Egger S (2006) Determining a sustainable city model. Environ Modell Softw 21(9):1235–1246. https://doi.org/10.1016/j.envsoft.2005.04.012

Enquist B, Edvardsson B, Petros Sebhatu S (2007) Values-based service quality for sustainable business. Manag Serv Qual 17(4):385–403. https://doi.org/10.1108/09604520710

European Commission (2017) World Cities 2014–2016: final report. http://ec.europa.eu/regional_policy/en/information/publications/reports/2017/world-cities-2014-2016-final-report

Fan P, Qi J (2010) Assessing the sustainability of major cities in China. Sustain Sci 5(1):51–68. https://doi.org/10.1007/s11625-009-0096-y

Grunewald P, Gerrard DM, Bateman N (2017) Open innovation in Health and Social Care: ICT supported co-creation of quality improvements. Loughborough, Loughborough University

Guzmán PC, Roders AP, Colenbrander BJF (2017) Measuring links between cultural heritage management and sustainable urban development: An overview of global monitoring tools. Cities 60(A):192–201. https://doi.org/10.1016/j.cities.2016.09.005

Hák T, Janoušková S, Moldan B (2016) Sustainable Development Goals: A need for relevant indicators. Ecol Indic 60:565–573. https://doi.org/10.1016/j.ecolind.2015.08.003

Harrison C, Donnelly IA (2011) A theory of smart cities. In: Proceedings of the 55th Annual Meeting of the ISSS-2011 55:1 Hull UK

Houghton C, Murphy K, Shaw D, Casey D (2015) Qualitative case study data analysis: an example from practice. Nurse Res 22(5):8–12. https://doi.org/10.7748/nr.22.5.8.e1307

Ishida T, Isbister K (2000) Digital cities: technologies, experiences, and future perspectives. Springer Science & Business Media, Berlin

Jacobs MA, Cobb CO, Abroms L, Graham AL (2014) Facebook apps for smoking cessation: a review of content and adherence to evidence-based guidelines. J Med Internet Res 16(9):e205. https://doi.org/10.2196/jmir.3491

Jenks M (2017) The sustainable city. A good and secure quality of life? In: Bay JHP, Lehmann S (eds) Growing Compact: urban form, density and sustainability. Routledge, Abingdon, pp 113–128

Kirwan CG (2015) Defining the middle ground: a comprehensive approach to the planning, design and implementation of smart city operating systems. In: International Conference on Cross-Cultural Design, Springer, Cham, pp. 316–327

Komninos N (2013) What makes cities intelligent. In: Deakin M (ed) Smart cities: governing, modelling and analysing the transition. Routledge, Abingdon, pp 77–95

Krippendorff K (2012) Content analysis: an introduction to its methodology. Sage, Thousand Oaks

Leech NL, Onwuegbuzie AJ (2011) Beyond constant comparison qualitative data analysis: using NVivo. School Psychol Quart 26(1):70–84. https://doi.org/10.1037/a0022711

Liao S, Chen X, Qian Y, Shen L (2017) Comparative Analysis of the Indicator System for Guiding Smart City Development. In: Proceedings of the 20th International Symposium on Advancement of Construction Management and Real Estate, Springer, Singapore, pp 575–594

Lombardi P, Giordano S, Farouh H, Yousef W (2012) Modelling the smart city performance. Innov Eur J Soc Sci Res 25(2):137–149. https://doi.org/10.1080/13511610.2012.660325

Nam T, Pardo TA (2011) Conceptualizing smart city with dimensions of technology, people, and institutions. In: Proceedings of the 12th Annual International Digital Government Research Conference: Digital Government Innovation in Challenging Times, ACM, pp 282–291

Newman P, Kenworthy J (1999) Sustainability and cities: overcoming automobile dependence. Island Press, Washington

Pickett STA, Boone CG, McGrath BP, Cadenasso ML, Childers DL, Ogden LA, McHale M, Grove JM (2013) Ecological science and transformation to the sustainable city. Cities 32:S10–S20. https://doi.org/10.1016/j.cities.2013.02.008

Redclift M (2005) Sustainable development (1987–2005): an oxymoron comes of age. Sustain dev 13(4):212–227. https://doi.org/10.1002/sd.281

Robert KW, Parris TM, Leiserowitz AA (2005) What is sustainable development? Goals, indicators, values, and practice. Environ Sci Policy Sustain Dev 47(3):8–21. https://doi.org/10.1080/00139157.2005.10524444

Rogers R (1998) Cities for a small planet. Basic Books, New York

Rogers M, Ryan R (2001) The triple bottom line for sustainable community development. Local Environ 6(3):279–289. https://doi.org/10.1080/13549830120073275

Satterthwaite D (1997) Sustainable cities or cities that contribute to sustainable development? Urban stud 34(10):1667–1691. https://doi.org/10.1080/0042098975394

Schaffers H, Komninos N, Pallot M, Trousse B, Nilsson M, Oliveira A (2011) Smart cities and the future internet: towards cooperation frameworks for open innovation. In: Domingue et al (eds) Future internet assembly, pp 431–446

Stemler SE (2015) Content analysis. Emerging trends in the social and behavioral sciences: an interdisciplinary, searchable, and linkable resource. Wiley, New Jersey

Surjan AK, Shaw R (2008) 'Eco-city' to 'disaster-resilient eco-community': a concerted approach in the coastal city of Puri, India. Sustain Sci 3(2):249–265. https://doi.org/10.1007/s11625-008-0051-3

Tregua M, D'Auria A, Bifulco F (2014) Digital City towards Smart City: a theoretical overview. In: Proceedings 2nd International Virtual Scientific Conference (SCIECONF)

Tregua M, D'Auria A, Bifulco F (2015) Comparing research streams on smart city and sustainable city. China USA Bus Rev 14(4):203–215. https://doi.org/10.17265/1537-1514/2015.04.004

UN (2015) Transforming our world: the 2030 Agenda for Sustainable Development. http://www.un.org/sustainabledevelopment/development-agenda/

Vanolo A (2014) Smartmentality: the smart city as disciplinary strategy. Urban Stud 51(5):883–898. https://doi.org/10.1177/0042098013494427

Werner P, Kelcey JG (2017) Urban green and biodiversity. In: Tan PY, Jim CY (eds) Greening cities. Springer, Singapore, pp 131–154

Zubizarreta I, Seravalli A, Arrizabalaga S (2015) Smart city concept: What it is and what it should be. J Urban Plan Dev 142(1):04015005-1-8. https://doi.org/10.1061/(ASCE)UP.1943-5444.000028