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Crowdsourcing urban sustainability. Data, people and technologies in participatory governance

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ABSTRACT

The aim of this paper is to prefigure the future of urban sustainability governance by implementing crowdsourcing-based solutions for governance processes.

We explore the convergence between recent research in urban sustainability governance and crowdsourcing. This is done by reviewing the literature in order to acquire important evidence to support the inductive process of theory building, and to highlight the upcoming trends in participatory research and policy-making that exploit ICT and Web 2.0 social software.

Our analysis indicates that a transformative relationship between data and people creates new forms of distant search for solutions and decision making. We argue that interest in crowdsourcing has expanded from computing researches to social and environmental applications. This new practical dimension unlocks the futures of integration of crowdsourcing into best practices in the governance of sustainability in an urban context.

Building on evidence that implementing crowdsourcing into the forthcoming governance of urban sustainability is increasingly recognised as a common priority, the paper suggests policy makers to devote more resources to ensure openness, transparency, interoperability and adaptability of crowdsourcing platforms.

1. Introduction

In recent decades interdisciplinary scholars have focused on cities as the appropriate space for researching innovative solutions for global sustainability (Breheny, 1992; McCormick, Anderberg, Coenen, & Neij, 2001; NÆss, 2001). The definition of policy priorities aimed at advancing urban sustainability principles has been addressed in all major U.N. meetings on environment and development, and has been included amongst the key issues in official documents (The United Nations, 1992; UN, 2002; MDGR, 2011; Rio+20, 2011).

At the same time, the Internet, personal ICTs and free software have led to bottom-up and urban sustainability-relevant data collection and data sharing through peer-to-peer and wiki-technologies. Similarly, high bandwidth storage and the Web 2.0 have been welcomed as a shortcut to the democratisation of governance processes (Brabham, 2013a; Bott & Young, 2012). Thus, crowdsourcing tools (e.g. smartphone software, blogs, wikis, social bookmarking applications, social networks, peer to peer software) and processes (e.g. social mapping, the collection of volunteered geographic information, geo-referenced social

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networking, co-designing, cloud processing, etc.) enable multiple web-based problem-solving, by involving large groups of users who perform functions (e.g. instantaneous broad communication, collection and analysis of big data, co-design, etc.) that would otherwise be difficult to automate or expensive to implement (Howe, 2006).

While crowdsourcing was originally defined as a web based business model requiring voluntary open collaboration in the development of creative solutions (Howe, 2006), it is now generally understood in the both scientific and grey literature as an online distributed innovation process (Brabham, 2008) that mobilises a number of dedicated tools for significant results also in public research and governance, too (Brabham, 2009; Brabham, 2012; Brabham, 2013a). It can thus be key in addressing challenging urban sustainability issues (such as energy consumption, transport efficiency, deprivation and unequal access to resources, water and sanitation, sewage, and the availability and distribution of environmental services).

The increasing circulation of information on the offline world through digital data is empowering a larger number of people to create new sustainability-oriented networks. Despite this, how crowdsourcing can foster virtuous governance towards the fulfilment of sustainability principles in the urban environment has only been marginally investigated.

In order to contribute to filling this gap, we explore the state of the art and prefigure future scenarios in science and urban governance characterised by the extensive diffusion of digital facilities, as well as the forthcoming development of crowdsourcing and its power to advance innovative participatory processes in sustainability-related fields.

We first survey the existing scientific and grey literature on urban sustainability and crowdsourcing, and then see how the two research areas can converge and offer new opportunities. We believe that integrating data from different, yet complementary research fields (environmental management, urban studies, science-technology and social studies, planning, etc.) can highlight the potential role of crowdsourcing in urban sustainability governance.

2. A longitudinal analysis of literature

How the extensive use of crowdsourcing tools can advance the governance of urban sustainability requires a theoretical exploration of the current transformation of data production/collection, management/elaboration and sharing processes. In addition entails pinpointing future-oriented signals emerging from everyday online activity which, despite being currently underground, are likely to lead to striking social transformations in the years to come (Glassey, 2012).

We used a three-step approach to analyse the largely unexplored intersection between crowdsourcing and the governance of urban sustainability:

1. We make a bibliometric analysis of the scientific production in the field of crowdsourcing and governance of urban sustainability;
2. We identify and classify the main theoretical contributions;
3. We ‘join the dots’ in order to develop new theoretical perspectives.

The first step involves testing a small set of relevant keywords that are expected to systematically occur within the body of relevant manuscripts. Through computer aided search and the extraction of records from the ISI Web of Knowledge database, publications are identified followed by a manual elimination of false inclusions (i.e. those manuscripts that only accidentally include the relevant keywords). Different streams of research are then analysed by map representations (van Eck & Waltman, 2010) in order to identify the most relevant clusters of theoretical contributions according to both relevance and centrality

A number of manuscripts, citations and impact factors of the journals were thus assumed as a proxy for the relevance of the manuscripts; closeness to the mainstream of the on-going debates was used as a proxy for the centrality. Each author of the present paper separately evaluated the closeness to the mainstream before agreeing on the final classification through a consensus meeting.

The second step involved analysing the logical connections between selected publications. Discussions with technical experts and colleagues held at the SDEWES 2013 conference led to a multi-disciplinary perspective, which was also adopted as the observational standpoint on grey literature. In the third step multi-disciplinary theory-building was exploited to join relevant elements from sectorial studies into a coherent logical framework.

2.1. Bibliometric research protocol

The analysis of scientific literature in the fields of “crowdsourcing” and “governance of urban sustainability” was based on a search of all the papers that include the pertinent keywords. Alternative key words were used(i.e. “crowdsourcing”, “crowd-sourcing”, “crowd sourcing”) as well as changes in the order of the words (i.e. “urban” AND “governance” AND “sustainability”). In addition the selected papers had to match the selection criteria at least once in the title, abstract or in the body of the manuscript.

In order to build a representative dataset of literature, we adopted the ISI Web of Knowledge academic citation indexing and search service. Besides providing bibliographic contents and tools to analyse research information, this is widely acknowledged as being reliable (Aguillo, 2011).

After the computer-aided extraction, the resulting publications included 473 manuscripts on crowdsourcing and 874 manuscripts on governance of urban sustainability. After an analysis of the titles of the papers retrieved, the list of papers

was refined by excluding those manuscripts that were too generic for our purposes (i.e. not specifically referring to the topics). In this refining stage, 219 articles were removed from the previous 1347. After this filtering procedure, a total of 1128 papers were selected and then scanned using *VosViewer* (van Eck & Waltman, 2010) and *Pajek* (Batagelj & Mrvar, 1998). This enabled us to create synoptic and surfable visual representations, i.e. term maps showing the most important terms in the titles and abstracts of publications and distributions of co-citations of the two research areas.

The resulting term map provided a visual representation of the relationship between the number of co-occurrences of the terms and the physical distance of words distributed on the map: the smaller the distance between two terms, the higher their co-occurrence in the 1128 articles.

2.2. Visual representation of research domains

Fig. 1 represents the terms that most frequently co-occurred (at least five times in the title, abstract and keywords) in the overall set of manuscripts in the fields of crowdsourcing and urban sustainability governance, processed by a natural language algorithm in order to exclude conjunctions, verbs, adverbs, adjectives, etc. In this term map, the grouping of terms clearly provides an indication of the juvenile links between the two areas of research. Assuming that the higher number of manuscripts in the field of governance of urban sustainability (i.e. a well-established field of research) is increasingly counterbalanced by the larger contribution in the field of crowdsourcing (i.e. a relatively new field), the thematic connections mainly refer to prospective applications of the latter.

Fig. 1 shows that the links between the two areas mainly concern a cluster of empirical applications of crowdsourcing approaches (CS2) and a cluster of empirical experiences of health (GUS 1) and environmental management in urban areas (GUS2). The other clusters, referring to social (GUS3) and economic (GUS4) aspects of urban development and technological aspects of crowdsourcing (CS1), are currently less covered by interdisciplinary studies. However, the dates of publication suggest that the overlap between crowdsourcing and the governance of urban sustainability is an emerging and promising field.

As shown in Fig. 2, co-citations confirm that the two research areas produce separate clusters. The main link is provided by a small number of papers on crowdsourcing in the environmental governance field.

Figs. 3 and 4 present a screenshot of the detailed term maps showing the internal composition of the two investigated domains (i.e. governance of urban sustainability and crowdsourcing, respectively) according to a threshold of seven co-occurrences.

Fig. 3 shows four main clusters. The largest and most representative, marked as GUS1, refers to social issues in urban environments. Theoretical contributions address some crucial problems for future urban development (such as criminality, unemployment, resource availability, or quality of life). This cluster is strictly connected with the GUS2, which more specifically refers to anthropic activities that have an impact on urban sustainability (i.e. traffic, industries, building expansion, etc.). Unlike the GUS3 cluster, which portrays economic sustainability and competitiveness issues through case studies in the developed economies, the yellow cluster features a larger number of case studies from emerging economies. Health and safety issues, grouped in the GUS4 cluster, are largely represented.

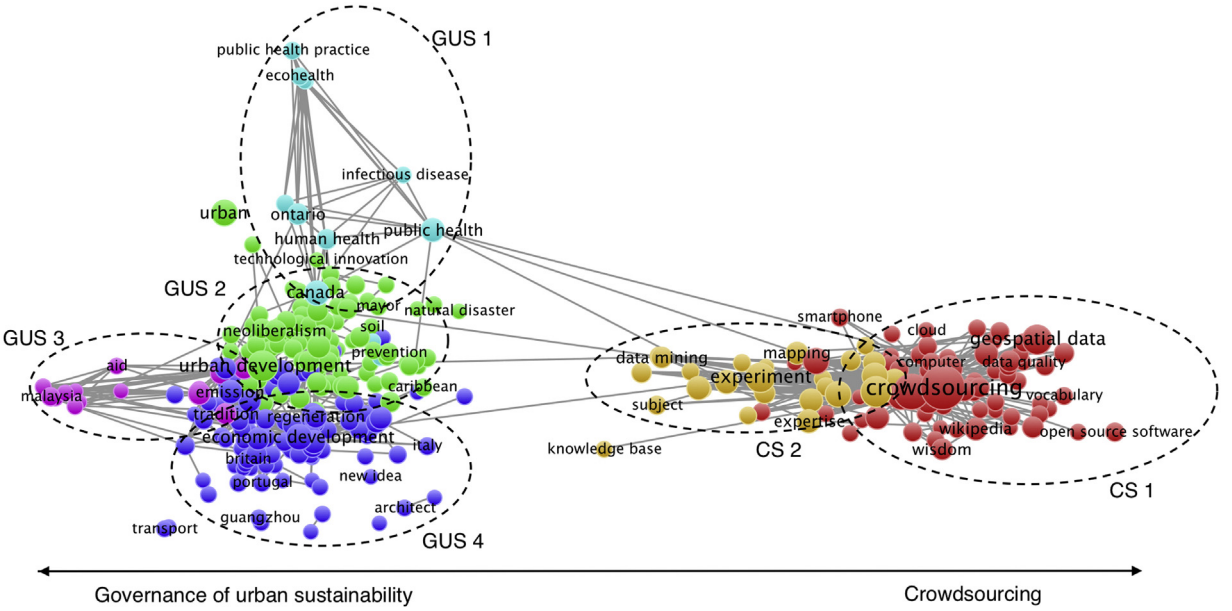

Fig. 1. Term map of manuscripts in the fields of crowdsourcing and governance of urban sustainability.

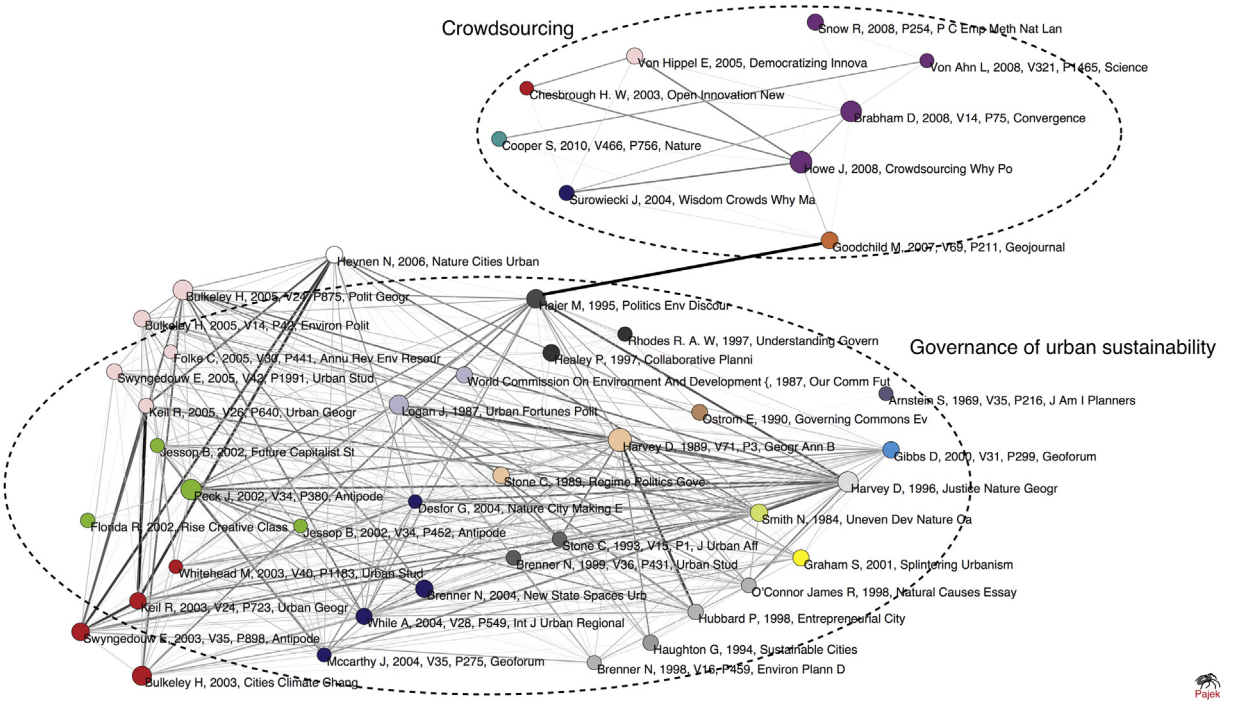

Fig. 2. Co-citation map of manuscripts in fields of crowdsourcing and governance of urban sustainability.

Interestingly, none of these clusters presents dominant methodologies for the acquisition and management of data in governance processes. Instead the topics had been explored using a variety of crowdsourcing-type processes including human perceptions (e.g. stress, sense of belonging, acceptability, quality of life, etc.), socio-economic dimensions (e.g. employment, health, social mobility, cultural identity, competitiveness, tourist attractions, contrast to poverty, economic performances, transport, etc.), and physical dimensions of the natural environment (e.g. natural disasters, air pollution, soil pollution, resource availability, etc.). Unsurprisingly, those areas more strictly related to participation in sustainability issues are, at the same time, those that generate a larger number of links with the crowdsourcing domain (see Fig. 1).

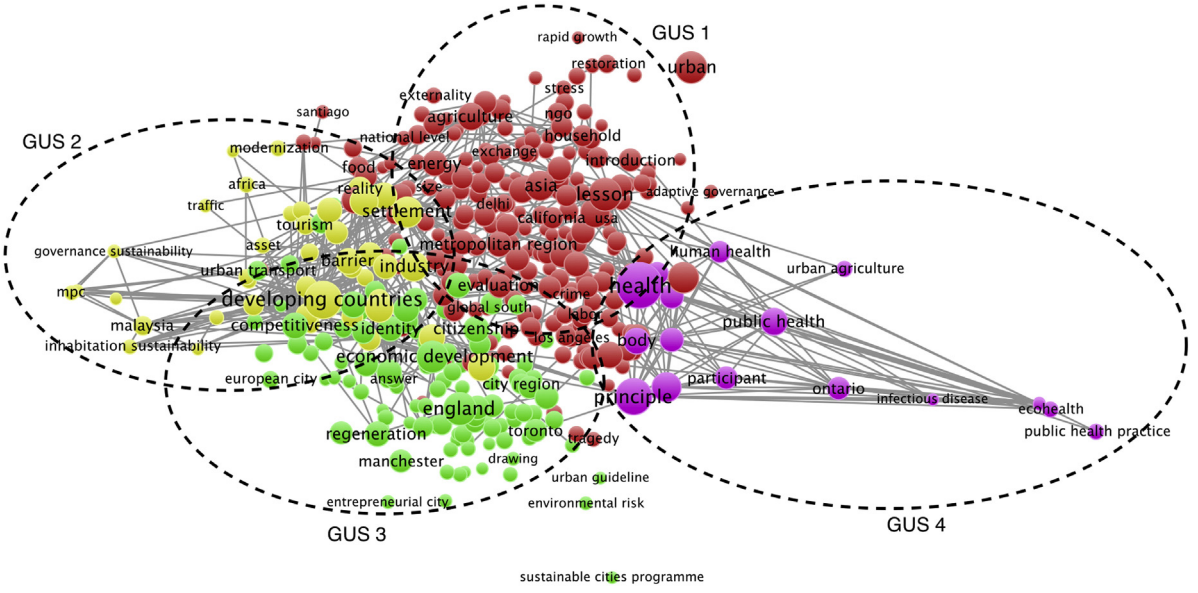

Fig. 3. Term map of manuscripts in the field of governance of urban sustainability.

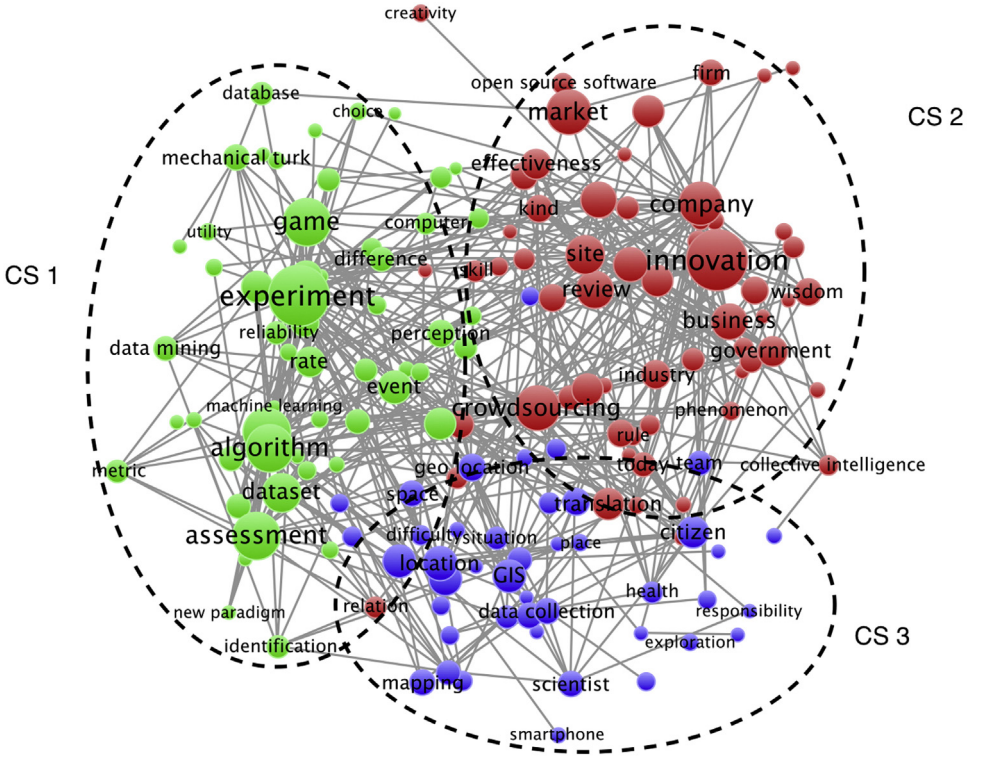

Fig. 4. Term map of manuscripts in the field of crowdsourcing.

Fig. 4 shows a clear distinction between the three clusters in the crowdsourcing field. The CS2 cluster gathers specific terms related to crowdsourcing tools and processes in manuscripts on business opportunities in innovation frontiers. The CS3 cluster refers to studies on the geographical analysis of territorial data (e.g. health, emergency management and other different types of public participatory GIS applications). The CS1 cluster aggregates a significant number of manuscripts dealing with operational aspects in data management with specific focus on the design of knowledge exchange platforms. Since these terms often relate to case studies and practical experiences, they have clear links with the field of urban governance.

Multidisciplinary perspectives seem more relevant in research on crowdsourcing, than research on governance of urban sustainability *and* crowdsourcing. This is probably due to the fact that crowdsourcing attracts the attention of product and service developers in many different fields. Such theoretical contributions typically go far beyond the availability of adequate case studies; whereas case-studies are numerically important in the governance of urban sustainability, which is clearly a broader field (Table 1).

3. Dominant paths of research in the field of governance of urban sustainability

Different but connected research areas emerge from an in-depth exploration of contributions from the complete set of papers provided by the longitudinal analysis. As shown in Fig. 1 the domains of crowdsourcing and urban sustainability governance aggregate two separate clusters of contributions in the scientific literature. However, environmental management in urban areas (green bullets in Fig. 1) is one of the topics attracting the interest of interdisciplinary scholars. This is confirmed by the analysis of co-citations (Fig. 2) showing that the most prominent (despite juvenile) link between the two domains is research on crowdsourcing in environmental governance. When considering the internal composition of the urban sustainability governance domain (Fig. 3), the case studies on socio-environmental issues in urban sustainability

Table 1
Number of papers and case studies in the fields of governance of urban sustainability and crowdsourcing.

	No. paper	No. case studies
Crowdsourcing	473	69
Gov.Urb.Sustain.	874	547

significantly highlight the importance of participatory practices and the possibilities offered by ICTs. On the basis of these results, in this section significant contributions are further analysed in order to highlight the most promising trends. These include (1) the (often non-trivial) definition of urban sustainability and its metrics; (2) the relation between participatory processes, enabled by social web and interactive ICTs, and governance processes; and (3) the increase, definition and forthcoming development of crowdsourcing tools and processes.

3.1. Urban sustainability: meanings and extension

Urban sustainability is rooted in the definition of sustainable development popularised by the Brundtland Report in 1987 (UN, 1987) and reaffirmed in the official documents produced by later international summits organised under the auspices of the U.N. (UNCSD, 2012; UNDESA, 1992; UNDESA, 2002). A myriad of alternative interpretations nuancing the Brundtland Report's words have emerged (Mebratu, 1998) and given rise to diverse courses of action, from weak to strong sustainability models (Neumayer, 2010) in both social economic and political domains (Rees, 1995). Documents on urban sustainable development (IDHA, 1996) have provided an agenda for a number of goals for cities in terms of, for example, slums, transport, health, water and sanitation, sewage, access to clean fuel and electricity, and local government capacity.

Strictly adherent to the Brundtland definition, Camagni described sustainable urban development "as a process of synergetic integration and co-evolution among the great subsystems making up a city (economic, social, physical and environmental)" (Camagni, Capello, & Nijkamp, 1998). Their integration is sustainable in so far as it grants the local population with a non-decreasing level of wellbeing in the long term; offers the surrounding areas with the possibilities of development; and provides solutions to reduce the harmful consequences of anthropic activity on the biosphere.

Despite the large consensus, the generality and ambiguity (Giddings, Hopwood, & O'Brien, 2002) of Brundtland's sustainable development definition have made it very difficult to be operationalised (Berke & Conroy, 2000; Keirstead & Leach, 2008). The cogency of the associated challenges (including the protection of ecological systems and their carrying capacity, the adoption of renewable resources, the fulfilment of basic human needs and promotion of inter- and intra-generational equality), however, have required continuous efforts to find the most appropriate solutions (Luke, 2005; Rees, 1995). Thus governance is key in defining how shared resources, spatial (infra)structures and design, production, consumption and waste generation patterns, management systems and government institutions can contribute to sustainability (Bulkeley & Betsill, 2005; Keirstead & Leach, 2008). The key role of cities in the definition of the global sustainability governance agenda has been widely recognised through the official documents issued by international organisations (IPCC, 2007; UN-HABITAT, 2010; German Presidency, 2007) and scholars (Sassen, 2006; Satterthwaite, 2007). They have focused on the *multidimensional* character of sustainability challenges which requires a balance between environmental protection measures, social cohesion and the provision of democracy (Fricker, 1998; Haughton, 1999). Thus special focus has been dedicated to implementing *participatory* approaches in governance processes to meet the increasing need for mediation in the socio-technical transition in the use of soft infrastructures (Hage, Leroy, & Petersen, 2010; Hodson & Marvin, 2010; Josza & Brown, 2005). In fact, the widening of the original idea of sustainability has also implied a broadening of aims and means of related governance processes. The concept of sustainability itself has been understood as providing a considerable degree of *adaptability*, by entailing a progressive, dynamic and mutable ideal of the future of sustainable cities' (Holden & Linnerud, 2007; Kallio, Nordberg, & Ahonen, 2007; Ratcliffe & Krawczyk, 2011).

A widely shared agenda that provides adequate conditions for greening the city while advancing *transparent* governance (Street, 1997) characterises urban sustainability as an ambitious and *purposive* task (Tonn, 2007). It requires city-wide investments aimed at knowledge sharing and involving people in designing and implementing based on technological leap-frogging and community-based decentralised knowledge.

The capacity of different urban actors to *collaborate* "to improve their natural, built and cultural environments at neighbourhood and regional levels, whilst working in ways which always support the goal of global sustainable development" (Haughton & Hunter, 2003) is fundamental in promoting social and environmental justice and *equality* (Larsen, Gunnarsson-Östling, & Westholm, 2011; Pearsall & Pierce, 2010) in the context of economic and environmental resilience (Daffara, 2011).

All these goals cannot be addressed by individual cities in isolation, but rather as part of regional and global *cooperation* networks (McGrahanan, 2005; Stren, White, & Whitney, 1992). Significantly, from the UNEP Johannesburg Summit in 2002 to the Rio+20 Summit in 2012, the profitability of partnership integrating economic incentives of the private sector, the on-the-ground experience of NGOs, the passions of ordinary citizens and the co-ordination of governments in addressing the specific challenges of sustainable development, has been a leading topic in the global environmental debate, and now plays a prominent role due to the Stakeholders' Forum in Rio + 20 Summit.

As the UNEP report "*City. Investing in energy and resource efficiency*" reminds us: "governance encompasses the formal and informal relationships linking the various institutions involved in the urban system–the local, metropolitan, regional, state, civil society and private-sector actors–and its quality depends on the depth of reciprocity, trust, and legitimacy. These are enhanced by mechanisms and opportunities to facilitate meaningful dialogue, and by well-structured organisations in civil society, the business sector and the relevant government level" (UNEP, 2011). It is thus not surprising that an increasing number of scientific contributions analyse how the current availability of digital technologies open up the possibility to rethink the form and organisation of cities from the extraordinarily long-term perspective required by the concept of sustainability.

3.2. Participatory processes and ICT for the governance of urban sustainability

Although information-sharing and participatory decision-making had already been considered by Agenda 21 as virtuous strategies for achieving sustainable development (Campbell, 1996; NÆss, 2001; The United Nations, 1992), it has become increasingly apparent that no policy measure can be effectively implemented without people's involvement in sustainability governance. Urban planners, data analysts and policy-makers have focused on the potential of participatory methods in terms of access and empowerment in city life (Haughton, 1999; Larsen et al., 2011). There are a considerable number of works on a broad range of participatory methods in science and politics (Chevalier & Buckles, 2013; Mikkelsen, 2005). The studies propose people's involvement throughout the research process (research design, data production/collection, data analysis/discussion/elaboration, definition of tools and procedures for data sharing and disclosure) (Greenwood & Levin, 1998; Noveck, 2009), and policy-making (priorities definition, policy definition, implementation measures, assessment) (Chakraborty, 2011).

While traditional participatory approaches have played an important role in (at least partially) enabling people to have their say in governance processes (Glass, 1979), they have often been charged for being inadequate in terms of inclusiveness, accessibility and degree of democracy. This means that real participation has turned out to be not so general, plural, or broad as expected, and has proved to have few consequences in terms of knowledge and power redistribution (Martínez & Rosende, 2011). People are accepted as legitimate stakeholders in commenting on alternative plans already provided by official policy-makers in seeking legitimation, but not in advancing autonomous proposals (Ledwith & Springett, 2010; Maier, 2001).

There is thus now great interest in extending the democratic and collective character of knowledge generation and its consequences in terms of governance (i.e. the emergence of e-governance). The current trend in participatory research is aimed at enabling people to collaborate with professional researchers using personal technological devices, information communications technology and sharing collected items, social software of the web 2.0 (including blogs, wikis, social networking), creative commons and open-access format (Hindmarsh, 2008). This trend reflects the innovative philosophy of systemic approaches to bottom-up control and democracy, thanks to the inter-operability of communication tools that make it increasingly harder to keep information secret (e.g. Wikileaks (Coleman, 2014)), and that have made government data protection vulnerable to the collective hacking of web activists. At the same time, citizen groups have become less vulnerable because transparency induces self-correcting behaviour, empowers advocacy, and requires consistency, quality and inclusion (Sharma, Kankanhalli, & Taher, 2013).

In addition to control, distant search for solutions is also reshaping participatory approaches. It is now widely recognised that the newly emerging form of collective intelligence (Levy, 1997), fuelled by interactive digital media, offers innovative possibilities for a broad public to be engaged (e-inclusiveness) in defining the future of sustainability science and governance processes. Despite this, recent criticism has toned down the optimism of ICTs-enthusiasts, as the possibility for these applications to actually unveil the hidden social understanding of reality and thus heavily influence future behaviours has been criticised because it is often supported by a new form of on-line collectivist faith in wisdom of the crowd (Lanier, 2006). However, this does not affect the evidence that interactive ICTs potentially provide useful tools and effective innovative models to strengthen citizens' engagement in the bottom-up production of ideas, knowledge, the framing of policies and the choice of regulative institutions (Pimbert, 2009).

3.3. Digital processes and crowdsourcing

In introducing a special issue of *Futures* on "Community Engagement for Sustainable Urban *Futures*", Hearn, Foth and Stevenson (Hearn, Foth, & Stevenson, 2011) claimed: "In the context of the field of urban planning and development, the promise of digital content and new media potentially serves new urbanist visions to develop and support social relationships that contribute to the sustainability of communities." (p. 358). They recognised, however, that community participation is very difficult to deliver. The possibilities offered by the huge amounts of user-generated data (still not in a systematic form) present clear signs of an upcoming revolution in the philosophy and practice of urban sustainability governance. This will be achieved by prefiguring the integration of environmental, social and economic priorities in urban governance; and reviewing the mode of interaction between governing bodies, research institutions and social actors (Nielsen, 2006).

Public involvement in scientific production may, in fact, increase direct participation in political life and encourage the expansion of public debate on some of the most pressing issues affecting society (Latour, 2009; Weibel and Latour, 2005). This is particularly important today when the governance of public affairs increasingly seems to be in the hands of experts and technicians; and the exclusion of people in the top-down scientific research model is combined with their exclusion from the governance of public affairs (Flyvbjerg, 2001). In a knowledge society where the availability of ICTs and scientific and technical data broadens people's power, the proliferation of participatory research programmes and open-source technologies is helping to reverse the existing geometries of power (Rushkoff, 2003).

Crowdsourcing is increasingly gaining a prominent role. It was coined by Jeff Howe and Mark Robinson in the June 2006 issue of *Wired* magazine (Howe, 2006) to describe a web-based innovative business model that involves voluntary open collaboration in the development of creative solutions. Daren C. Brabham was the first to use the term in the scientific literature in 2008 which he defined as "an online, distributed problem-solving and production model" (p.243). While originally used in the business and computer science sectors for externalising difficult or expensive programmes/content

generating functions (outsourcing), crowdsourcing has been now adopted to indicate any open call format and also the large network of potential users fostering distant creative power in public governance sector (Brabham, 2009; Brabham, 2013a).

A thorough analysis of the origins and the different understandings of crowdsourcing was provided by Enrique Estellés-Arolas and Fernando González Ladrón-de-Guevara (Estellés-Arolas & González-Ladrón-De-Guevara, 2012) who concluded by proposing a comprehensive definition (Estellés-Arolas & González-Ladrón-De-Guevara, 2012): "Crowdsourcing is a type of participative online activity in which an individual, an institution, a non-profit organisation, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task" (p.9). The task can be of variable complexity and the crowd can participate by providing work, money, knowledge, data, etc.. . ..The results are beneficial for both the actors requesting crowd participation, and for those taking part in the crowdsourcing process, as it may help to satisfy some of their needs (e.g. economic, social recognition, self-esteem, or the development of individual skills).

Unlike existing approaches enabling users to generate their contents (e.g. WikiPlanning), an internet-based group in crowdsourcing is loosely coordinated and users have a higher degree of freedom to develop ideas and proposals (e.g. CivicEvolution). This means that in some cases data are just accumulated with no interrelation between users and no interpretation by third parties (Hudson-Smith & Batty, 2009). In other cases the interaction between users generates an extra value to the collected data (e.g. CitizenScape). The main difference between crowdsourcing and other forms of online participatory culture and user-generated content activities (e.g. lead-user innovation, online problem-solving, human computation etc.) is that the source of control in crowdsourcing lies between the organisation and the online involved community (e.g. open-source software projects) (Brabham, 2013b).

A complete catalogue of the large, heterogeneous and unregulated world of crowdsourcing is almost impossible to provide; however all crowdsourcing processes rely on the technological agency of people (Goodchild, 2007; Haklay & Weber, 2008) using personal ICTs for collective peer-production (Brabham, 2008) to record, measure, report on the external environment; to share opinions, ideas and experiences; and to elaborate data and create open innovation. Many different uses of crowdsourcing can be found in both academic research and the practices. While generating crowdsourcing processes and adopting crowdsourcing tools, they do not explicitly refer to crowdsourcing (for instance, the engineering literature on sensing technologies for environmental data recording rarely refers to crowdsourcing yet often uses them in practice). Amongst others, the following fields for crowdsourcing processes and tools have been identified in the interdisciplinary literature:

- The potential of crowdsourcing in effectively mobilising collective intelligence has already been demonstrated in computer science through open-source software (e.g. Linux, Ubuntu), collaborative contents (e.g. Wikipedia), or multiple content aggregators (e.g. Flickr, YouTube and Twitter). By going beyond the setting up of information coding and sharing, today crowdsourcing supports the increase in knowledge through new big-data analysis applications (e.g. data mining software, such as Many Eyes; or cluster and social networks software, such as NodeXL) that describe the hidden semantic geographies of the web.
- Crowdsourcing often complements Citizen Science initiatives (i.e. systematic knowledge production and interpretation by non-professionals through collaborative means). These initiatives generally involve the participation of ordinary citizens in for example collecting data and disseminating results. This includes a networked system of sensing devices, social media and mobile communication networks for data-processing (e.g. Citizen Cyberlab EU project), and collaborative peer-production of "do-it-yourself" technologies (e.g. Public Lab organisation or the HackteriaLab2014) (Golinelli and Ruivenkamp, in press)
- Social mapping is another expanding field of crowdsourcing. These methodologies were first developed when Google licensed maps and aerial images for free (Hudson-Smith & Batty, 2009)., Despite this, OpenStreetMap images, published under the Open Database License is also available (Haklay & Weber, 2008) for map creation (e.g. GMapCreator), data management and storage (e.g. MapTube), peer-to-peer and information sharing (Crampton, 2009), and improving the functionalities of the maps themselves.

4. Current trends and future integration between crowdsourcing and the governance of urban sustainability

We have taken the extensive definition provided by Enrique Estellés-Arolas and Fernando González Ladrón-de-Guevara (Estellés-Arolas & González-Ladrón-De-Guevara, 2012) as the most adequate to describe the current trend and future potential of crowdsourcing, particularly in the field of urban sustainability governance. In fact, despite being originally intended to define consumer oriented solution-seeking demands by business operators, today crowdsourcing refers to any citizen-inclusive approach aimed at focusing public priorities and shared procedures and at fostering innovative contributions in knowledge management and policy making. While some disciplinary jargon persists in the definition of problem-solving web-based participatory processes, the evidence from both the scientific and grey literature show that there is increasing consensus on the non-restrictive understanding of the term crowdsourcing, and a gradual broadening of its sphere of application.

Many private companies (e.g. Unilever, Heineken and Sony) exploit crowdsourcing as a shortcut for addressing their business challenges in sustainability (e.g. water, waste, long chain distribution and production) by launching open crowdsourcing platforms. These are aimed at helping people to set up priorities and find suitable ways for achieving them.

Crowdsourcing can thus be regarded as nothing more than an attempt at capitalising on public problem solving by painting CSR with a new participatory tone. However, we claim that, when crowdsourcing is defined in extensive terms as in (Estellés-Arolas & González-Ladrón-De-Guevara, 2012), it offers innovative suggestions for improving the future of public participatory governance too. As Phil Drew noted in *The Guardian*, there are a number of reasons for private business to choose online crowdsourcing and open-source innovation especially when dealing with sustainability research and development. First of all, enlightened companies know that sustainability is not a "pimp your business option" but a pressing imperative. Second online platforms create strong networks with a large community of entrepreneurs, academics, NGOs and other businesses. Third, when measuring total environmental impact, consumer behaviour is so important. By enabling them to have their say, it is possible to affect their environmental preferences and search for sustainable products; lastly, co-creation is a powerful design and marketing tool. However, crowdsourcing is not only a way to engage people but also a way for being engaged by people and to appreciate their concerns (Leighninger, 2011). This marks a clear difference between crowdsourcing by commercial companies for to increase their business and the more explicitly social, environmental and political crowdsourcing processes. The latter often include people-inspired and people-led initiatives whose potentiality to engage a broad public relies on the strength and interest of the values involved (such as producing a benefit for everybody, sharing knowledge, allowing silenced or under-represented subjects to have their say). Therefore, crowdsourcing is increasingly being appropriated by NGOs and civil society organisations, as in the WWF's "Open Planet Ideas" project or in the organisation ChangeMakers' programmes; and by public administrations, e.g. the case of the US government's campaign "Challenge", or the EU's "Digital Agenda for Europe 2020" that aim to facilitate a web 2.0-oriented governance of sustainability (European Commission, 2010).

An interesting classification of various current projects is in the way data are produced and shared (Fig. 5).

The evolution and the state-of-the-art of such experiences increasingly integrate the use of sensors and people engagement techniques (PETs). In addition, there is a move towards open data in those experiences that refer more to the governance of urban sustainability. This is in line with the fact that the massive use of technological devices in daily life and in scientific knowledge is making classic data production (i.e. the extractive research approach) and its traditional use obsolete. A new appreciation is thus required of the urban space as the laboratory for new multimedia, multiusers and interactive forms of scientific representation and political representativity. As a consequence, urban sustainability is

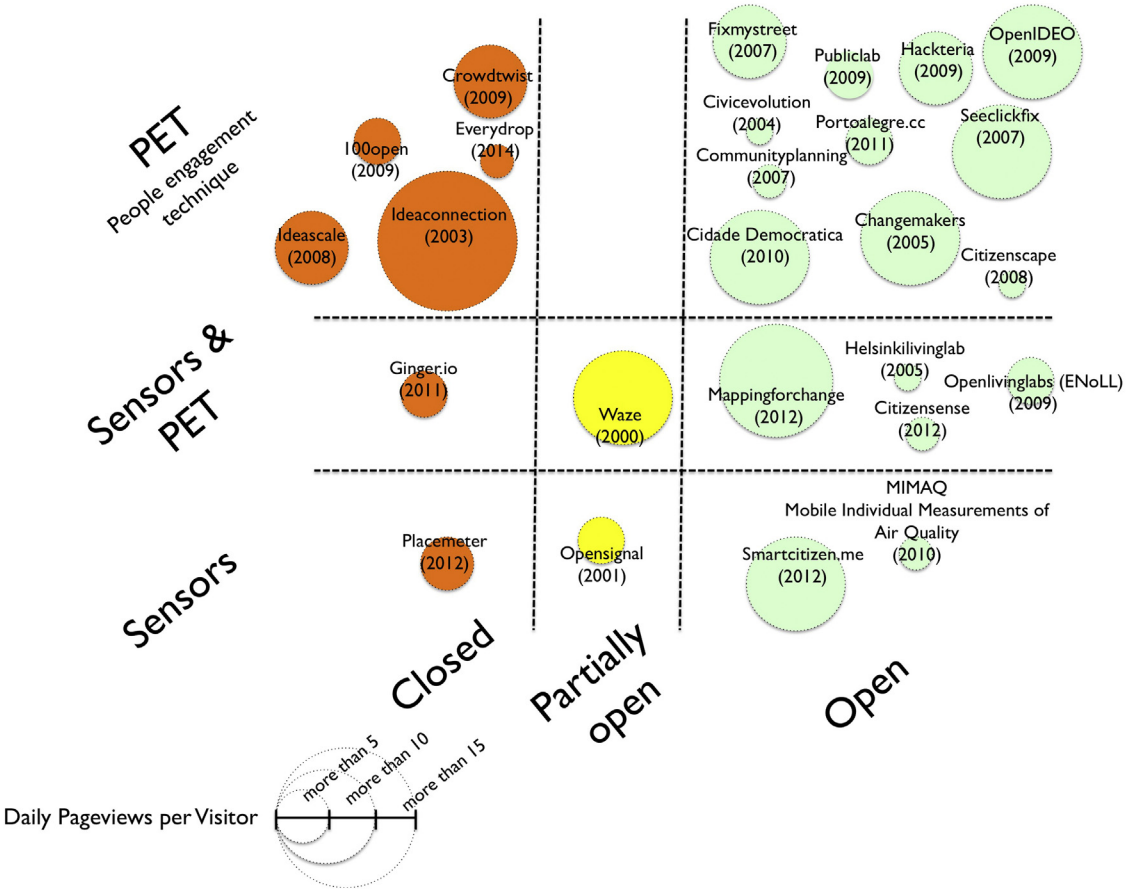

Fig. 5. Classification of various crowdsourcing projects according to the ways data are produced and shared.

increasingly regarded as the appropriate terrain for testing the efficacy of crowdsourcing in upgrading the participatory dimension of knowledge production and policy-making, by fostering the combined action of public and private sectors.

From a knowledge production point of view, a number of recent cases in Europe have focused on complex actor-networks in urban sustainability governance processes (Barry, 2001). Amongst others, the European project FP7 "EveryAware", for instance, aims to integrate all the crucial phases of urban environmental management (environmental monitoring, awareness enhancement, behavioural change) into a unified framework. This is done by creating a new technological platform combining sensing technologies, networking applications and data-processing tools, hosted by internet and mobile communication networks. Again, the ERC-founded project "Citizen Sensing and Environmental Practice" investigates the relationship between the technologies of environmental sensing and citizen engagement, via wireless sensors (Gabrys, 2012). This analyses the role of technological tools and virtual procedures in linking together all the social actors who are involved in the same environmental-related issue; and defines social agency as the result of this networking operation (Wiedemann and Zehle, 2012). It highlights the material entwining and enfolding of electronic and high-tech media that turn humans, non-humans and technologies into co-agents in data and knowledge-production and decision-taking (Parikka, 2011; Weibel and Latour, 2005).

From a governance point of view, crowdsourcing tools and processes have already been adopted by several municipal administrations worldwide. Of the most representative examples, the crowdsourcing platform "OpenIDEO" is worth mentioning. It was set up by the design firm IDEO 2010 in order to help in the search for a viable and affordable solution to some of the most pressing societal challenges, including urban sustainability, in the city of Detroit. Specifically, it is aimed at finding a way forwards out of the industrial crisis through a multi-step process of empowering peoples' ideas while simultaneously improving them. Another examples is the "Give a minute" programme currently being run in New York, Chicago and Memphis, as part of the city's strategic planning. It enables residents to directly crowdsource changes in their cities via social network-based calls issued by real estate development teams in partnership with the city government.

Based on the analysis of the most recent experiences in socio-technical innovation, Table 2 shows how crowdsourcing processes and tools can help in designing the future of urban sustainability governance. In the first column a list of key words presents the main characteristics of urban sustainability governance as in the literature analysed in Section 3. The second

Table 2
Future directions in urban sustainability governance through the implementation of crowdsourcing.

	Urban sustainability governance requires	Crowdsourcing will impact the future by	This prefigures a future characterised by
1	Participation: people involvement in knowledge production and batch decision-making (Campbell, 1996; Hage et al., 2010; UNDESA, 1992).	Allowing technology-mediated forms of public participation in science and policy production (Brabham, 2009; Willett, Heer, & Agrawala, 2012).	Ad hoc design of freely accessible crowdsourcing platforms issued by research and policy-making institutions (ex. *Citizen Sense*, *PublicLab*)
2	Multidimensionality: balance of the ecological/environmental measures with social measures (Fricker, 1998; Keirstead & Leach, 2008).	Helping social actors to establish pro-active relationships with the environment (Gabrys, 2012).	Use of sensing tools and procedures for improving the perception of environmental conditions (ex. *Extreme Citizen Science*, *Communitymaps)*
3	Purposiveness: operationalise principles of ecosystem protection, environmental management and the fulfilment of basic human needs (Tonn, 2007; UNEP, 2011).	Feeding problem-solving through direct contact between scientists, citizens and administrators with standardised on-line based processes (Brabham, 2008).	Diffusion of interactive platforms for sharing solutions and implementation tools between citizens and institutions (ex. *Citizen Cyberlab, openIDEO*)
4	Equality: mechanism to promote social and environmental justice (recognition, redistribution, empowerment) (Haughton & Hunter, 2003; Larsen et al., 2011)	Distributing agency in data production, collection and interpretation, and in policy-proposal elaboration (Bailey & Grossardt, 2010; Brabham, 2012; Eames & Egmose, 2011).	Web-platform for creating brand-new sets of data (or feeding existing ones) (ex. E*veryaware project*, *Mapping for Change*)
5	Transparency: advancing effective democratic institutions (Street, 1997; UNEP, 2011)	Granting access to meaningful information, data and software (Barsotti, 2009).	Increase in open-access knowledge and open-data provided by research, political and administrative institutions (ex. *Open Data Aarhus, Environmental Agency DataShare)*
6	Collaboration (internal): a substantive agenda that is sharable by institutions, businesses, civil society organisations, NGOs and people on the basis of reciprocity (Daffara, 2011; UNEP, 2011).	Allowing institutions, businesses, civil society organisations, NGOs and people to negotiate in the virtual space the fate of an issue on a non-discriminatory base (Marres, 2005).	City-based and issue-oriented collaborative platforms (ex. *Sustainable City Network, The Community Planning Websit*, *Cidade Democratica*)
7	Cooperation (external): links between international and transnational actors in order to global environmental goals (Haughton & Hunter, 2003; Stren et al., 1992)	Developing a cross-border public space without the need for institutional mediation and the physical presence of all actors (Lemke, Casper, & Moore, 2011; UNEP, 2011).	Interconnectedness of local issues in the global arena, shared practices and creation of distance-actions (ex. *GlobalVoices*, *Hacking the city)*
8	Adaptability: progressive and dynamic goal-changing agenda (Holden & Linnerud, 2007; Kallio et al., 2007; Ratcliffe & Krawczyk, 2011).	Undertaking tasks of variable complexity and modularity in which the crowd contributes work, money, knowledge and/or experience (Estellés-Arolas & González-Ladrón-De-Guevara, 2012).	Software to collect the voice of the general public provided by institutions or business (ex. *IdeaConnection*)

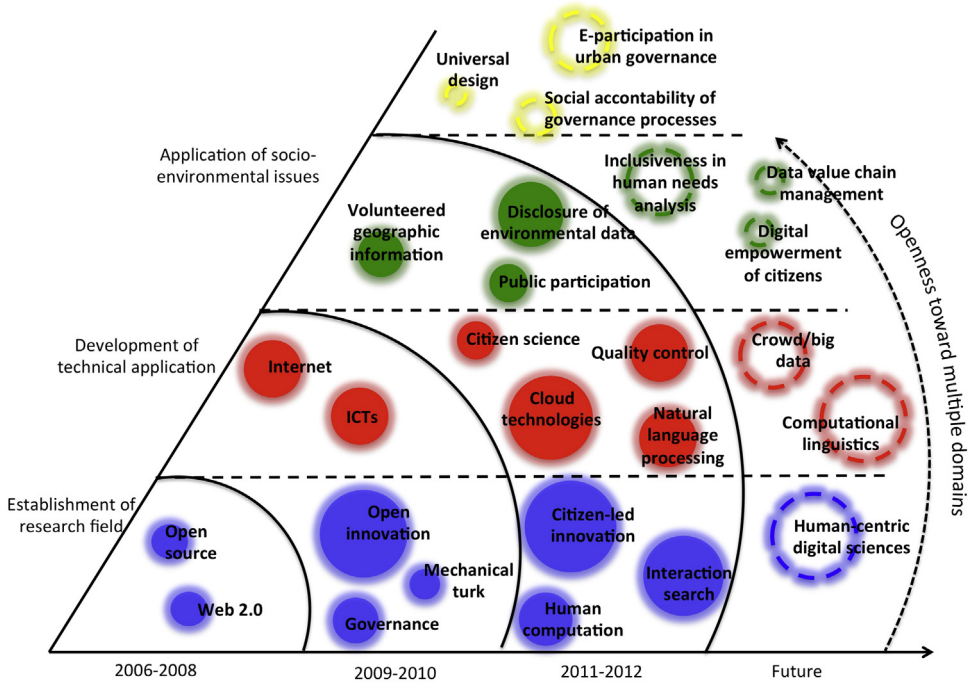

Fig. 6. Visual elaboration of the evolution of interest clusters in the crowdsourcing literature and some future developments.

column suggests how crowdsourcing will impact the future governance of urban sustainability, mainly on the basis of the literature analysed in Section 4. The third column prefigures the distinctive attributes of future urban sustainability governance by integrating crowdsourcing processes.

The table highlights that when crowdsourcing is understood as a data-collection and ideas-sharing process, it can lead to a broad appreciation of sustainability challenges in the urban context and innovative forms of collaboration. Crowdsourcing is particularly able to facilitate active citizen participation and to promote the environmental and social goals of urban sustainability, through transparent, purposive, continuous and innovative processes, by at the same time supporting internal collaboration and external cooperation in a globally connected urban governance model (Fig. 6).

5. Conclusions

By critically analysing the converging points between crowdsourcing characters from the scientific and grey literature, and the requirements of urban sustainability and participatory practices, our findings show that:

I. as one of the most ground-breaking forms of participatory knowledge production and decision-making approaches, crowdsourcing has some characteristics (such as publicity, openness, inclusion and accessibility) that seem to fit well with the requirements of urban sustainability as defined in Table 2;
II. the governance of urban sustainability can benefit from different crowdsourcing approaches or participatory science-power, as in Table 2. They can be adapted to different contexts according to specific environmental, social, political and economic needs, as long as they are aimed at advancing participatory governance and the related goals of recognition, participation and redistribution (for redistribution, see (Haughton, 1999));
III. The governance of sustainability can promote the adoption of crowdsourcing as a way to increase transparency and effectiveness by reshaping the relation between data availability/management, public empowerment and the pursuit of sustainability.

Although no previous evidence has been highlighted a single direction for integrating crowdsourcing processes and urban sustainability governance, our findings suggest that crowdsourcing processes and tools can be profitably adopted to advance urban sustainability governance.

5.1. A crowdsourced future for urban sustainability governance

Our bibliometric analysis shows the progressive pervasiveness of crowdsourcing in various perspectives mostly linked to the governance of future sustainability.

Graph 1 classifies the trends in different scientific areas based on the key-topics of the papers selected from the bibliometric analysis on the crowdsourcing cluster (see Section 1). This shows that from a preliminary interest in the establishment of a research field (first level) and in the development of technological applications (second level), crowdsourcing is now being investigated jointly with innovative public-private governance processes and government implications (Brabham, 2013b). The pervasiveness of digital infrastructures in urban contexts is transforming traditional urban governance (Batty et al., 2012). We thus expect that social issues will attract increasing attention from the public–more than private–actors in the exploration of human-centric digital futures (third level, in particular in the section "Future"). This expectation can only face a modest challenge related to the exploitation of diffused capabilities, data and infrastructures that derives from the deficiency of current regulatory provisions related to ownership and management of future crowdsourcing platforms.

Specific interest in socio-environmental issues, at present largely advanced by citizen science programmes (see red bullets in 2011–2012), VGI and data disclosure processes (green bullets in 2011–2012), is also likely to expand and to focus on citizens' technological agency (third level, section "Future") and participation in urban governance (fourth level, section "Future"). The convergence of governance-related crowdsourcing applications (fourth level) and the potential of citizens' empowerment in environmental-data generation and management (third level) will probably lead to research in the crowdsourcing domain dealing with the governance of sustainability. Such fuzzy clusters are likely to expand in the very near future by the joint actions of public administrators and private businesses aimed at establishing practical norms and tools (fourth level) to exploit the full potential of voluntary and multi-purpose data, i.e. data that can be mined without incurring privacy or transactional problems.

5.2. Directions in forthcoming crowdsourcing-based governance

The future trends in crowdsourcing data for sustainability also need to be looked at with greater attention by company managers. Although companies have started to disclose more information on their social and environmental performance through sustainability and social reports, recent research, highlights that:

- these reports are read by a relatively low number of external readers (Johnson, 2012);
- there is a barrage of data that lacks the necessary context to assess its relevance and understand possibly misrepresented data (which could improve the public reputation of a company) (Sarfaty, 2013).

The diffusion of citizen sensing/reporting tools and the aggregation of such data on user-friendly sharing platforms are likely to deliver more information than sustainability and social reports. Thus those companies able to provide constant sustainable indicators will gain a competitive advantage in the long run by considering both:

- the future increase in social pressure and social sanctions introduced by crowdsourced data (e.g. boycotts, activism);
- the future possibility of active enforcement, through sanctions and fines, related to regulatory violations and deliberate misrepresentations of the accuracy of corporate data.

Companies also need to recognise that they cannot halt the current trends towards citizens' empowerment in both business and public governance.

The inevitability of a crowdsourced future is also expected to induce policy makers to devote more resources to:

I. "openness": encouraging the extension of open access data, as suggested by the European Commission endorsement to open up public sector data for re-use across Europe (on the basis of recent evidence, this will become increasingly common in the near future) (EC, 2013);
II. "transparency": extending crowdsourcing platforms by fostering the transparency obtained through this flow of information;
III. "interoperability": integrating crowdsourced data with open government data;
IV. "adaptability": preventing technological and infrastructural lock-ins that could give rise to new hidden monopolies.

Considering the novelty of the area of research, and the expected and important future development of crowdsourcing for governance, we argue the need for further empirical research. This would help us to understand the theoretical pattern matching, as it enables crowdsourcing processes and technologies to be more effectively implemented in urban sustainability governance (e.g. case studies regarding different typologies of crowd data collection/integration with open data; data verification case studies for accuracy and consistencies). In addition, future research will be crucial in assessing means to manage the value chain of crowdsourced data so as to avoid asymmetries in the appropriation of the related benefits.

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