Spatial Data Management and Visualization Tools and Technologies for Enhancing Participatory e-Planning in Smart Cities

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Abstract In recent years the concept of "smart cities" has emerged as a new promising paradigm for urban management, capable of attaining sustainability objectives. The issue of citizens and stakeholders' participation, whose contribution to the collection of empirical knowledge, identification and prioritization of urban inefficiencies as well as selection and deployment of city- and citizen-specific smart applications and policies for coping with these inefficiencies and steering sustainable, inclusive and resilient urban environments, is of critical importance and lies at the heart of this new paradigm. Digitally enhanced environments, supported by Information and Communication Technologies (ICTs) and their applications have marked a noteworthy shift towards e-Planning and e-Participation, setting the ground for more knowledgeable policy-making towards the planning/implementation of smart city solutions that are mostly citizens- and city-oriented rather than purely technology-pushed. The focus of the present paper is on the delineation of participatory e-Planning as a digitally enabled perspective for effectively communicating various planning problems to citizens and stakeholders and actively involving them in decision-making. Along these lines, the most significant tools and technologies are described, which are currently available in planners' portfolio in order for participatory planning exercises to be optimally implemented by successfully integrating spatial planning approaches, public participation and visualization techniques; while the role of Public Participation Geographic Information Systems (PPGIS) in spatial planning is also discussed. Finally, some concluding remarks are drawn as to the key components and obstacles planners are confronted with, while carrying out participatory e-Planning projects in a smart city context.

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1 Introduction

Urbanization constitutes nowadays a rapidly expanding global phenomenon, which, according to United Nations' estimations, is expected to be further intensified by 2050 (Oracle 2011). The impacts of this escalatory urbanization trend are already evident in numerous sectors and urban functions, e.g. intensity of water and energy consumption, increasing volumes of urban waste, traffic congestion, inadequate infrastructures, insufficient energy for satisfying the constantly raising demand, ascending pollution levels, lack of social cohesion, etc. What is fully realized as to the future development of urban environments is that cities are already or will soon be confronted with great challenges, threatening their future sustainability. Policy makers and planners, in this respect, are those in charge of elaborating on these impacts so as to come up with effective and sustainable solutions that can successfully address them. Additionally, the rapidly changing global environment, marked by *key drivers of change* such as overpopulation, climate change and its impacts, water scarcity, poverty, migration waves, etc., renders the overarching challenge of *sustainable urban development* a key planning goal and a moving target in the policy agenda (European Union 2011).

Within such an environment, the radical developments regarding ICTs and their applications that can support a plethora of urban functions and provide upgraded services to citizens, businesses, public and private agencies, have significantly altered a number of scientific fields and relating processes, among which is also *spatial planning*, by providing new approaches, tools and technologies for pursuing sustainability objectives; and broadening the perspective of citizens and stakeholders' engagement in such an effort. The latter is considered by many researchers quite critical for the efficient management of current urban problems (Duany et al. 2010; Bizjak 2012; Seltzer and Mahmoudi 2013; De Pascali 2014; Steiniger et al. 2016).

Intensive and wide ICTs' exploitation in the urban context brings to the forefront the concept of *smart cities*, as innovative urban environments which, through the adoption/use of technology, seek to achieve sustainability objectives and encourage engagement of citizens, businesses and other stakeholders of local ecosystems in decision-making processes. According to the literature review, although numerous "smart city" definitions have been proposed from time to time, a clear and commonly accepted one does not still exist. Some of them are totally technology-oriented, considering ICTs as the dominant developmental lever for urban environments, while others adopt a broader and more integrated approach, incorporating aspects of society, economy, and governance as well as participatory approaches in attaining sustainable urban development objectives (Manville et al. 2014). Despite the aforementioned differences, it is largely recognized that a smart

city is a city that uses ICTs in an innovative and efficient way so as to manage urban problems and infrastructures; support competitiveness and local prosperity; and create knowledgeable, aware, creative and active citizens as *carriers of urban change*, an issue that is significantly enhanced through their participation in decision-making procedures.

Within the ICT-enabled environment that a smart city represents, the concept of *participatory e-Planning* is gaining great importance. Participatory e-Planning implies a digitally-enabled planning process which effectively integrates spatial planning approaches, public participation and visualization techniques in an effort to support the cities' "going smart" journey and develop or follow city- and citizens-specific planning solutions fulfilling at the same time needs, expectations and visions, but also sustainability objectives of local urban environments.

Towards this end, the *focus* of the present paper is on sketching the *main portfolio* of digitally-enabled tools and technologies that are available nowadays for implementing e-Planning exercises. In such a context, the next section is briefly describing the rise of participatory planning as a new paradigm, followed by a general discussion on the digitally-enabled planning process known as participatory e-Planning. Next, the delineation of the most important tools and technologies that are at the service of contemporary e-participatory spatial planning is presented. The paper proceeds with the description of the role of Public Participation Geographical Information Systems (PPGIS) in the spatial planning process, while finally some comments on the key components and obstacles hampering the implementation of participatory e-Planning in the context of smart cities are made.

2 The Participatory Planning Paradigm

Planners and decision makers are nowadays confronted with *wicked problems*, i.e. problems that are quite difficult to be solved due to mainly the: incomplete or contradictory knowledge; number of people and opinions involved; large economic burdens these bear; and the strong interconnected nature of these problems with other problems. For example, poverty is linked with education, while nutrition is linked with poverty, and economy is considered a defining factor for nutrition, and so on. According to Balint et al. (2011), confrontation of wicked spatial planning problems is fraught with many difficulties, mainly emerging from two types of uncertainty: the first relates to scientific uncertainty of solutions these problems entail; while the second to the uncertainty as to the way these solutions will be grasped and accepted by the recipients i.e. the various societal and stakeholders' groups, driven by different perceptions, motives, behaviors, etc. (De Roo and Porter 2007).

Coping with wicked planning problems that are common in evolving urban environments has brought to the forefront the need for policy makers and planners to develop or adopt *new ways of thinking*. Such ways is necessary to be grounded on a deeper and multidimensional exploration of current and possible or desired future states of cities and their interrelations, as well as the potential paths linking,

in a sustainable way, current state and desired future ends. Moreover, they should be grounded on the exploration of the potential perception of the various planning interventions by different social groups which, taking also into account power relationships within urban environments, can dramatically affect implementation of planning solutions, by either supporting or opposing to planning propositions. Finally, effective management of urban wicked problems in rapidly changing urban environments needs to be based on *new methodological approaches*, which are far away from rational planning thinking of the past; and are capable of exploring *new opportunities* and support *innovative and inclusive solutions* that can efficiently confront wicked problems and ensure wide consensus and commitment to planning outcomes.

Additionally, urban problems need to be solved within a volatile external environment, mainly characterized by *complexity* and *uncertainty* as well as rapid pace of mostly unpredicted changes in all respects, where solutions identified should be implemented quickly, before becoming obsolete. As Friend and Hickling (2011) claim, planners, while seeking solutions to wicked problems, are confronted with *three types of uncertainty*, namely:

- uncertainty related to the *value system* of planning efforts' recipients (values, priorities, visions, etc.), which constitutes the "lens" through which planning interventions are grasped and understood;
- uncertainties as to the developments of the *external environment*—the decision environment—which are framing the context where planning decisions will be made; and
- uncertainty as to the *decisions made*, where the planning problem at hand is largely interconnected with other problems, while a variety of decision-making bodies, at different hierarchical decision levels, are activating and their decisions can affect the effectiveness of planning exercise on a certain problem.

Facing the above uncertainties has pushed forward, among others, the current direction of *participatory planning*, aiming at exploring underlying principles of spatial entities' value systems that constitute the core of planning exercises and will largely affect decision-making processes and outcomes that best fit to these entities (Hennen 1999; Kanji and Greenwood 2001; Pereira and Quintana 2002; Puglisi and Marvin 2002; Mostert 2003; Innes and Booher 2004; Hines and Bishop 2006; Stratigea 2015). Indeed, planning and managing the city in an uncertain and rapidly evolving world and dealing with wicked problems implies gathering of *collective intelligence* (Conklin 2005). This, in turn, entails collection of *distributed knowledge*, representing perspectives, understandings and intentions of various diversified actors that activate and operate within cities. This is largely justified by the diversified perceptions different actors have on what the planning problem is or what constitutes an acceptable solution to this problem. A deep insight into these perceptions as well as an effort to achieve a certain compromise out of them and end up with a *shared view* of planning problems and related solutions, coupled with *commitment* to their implementation is a prerequisite for effective planning

nowadays. In order for this goal to be fulfilled, there is a need to address and understand *social complexity*, i.e. the number and diversity of actors (citizens and stakeholders) who are directly or indirectly affected by or can contribute to the solution of a problem and related value systems; and effectively embed this knowledge into the planning process (Conklin 2005).

In recent years, *participatory planning* is considered as one of the leading approaches or a *new paradigm* in planning, fulfilling the goal of peoples' engagement in decision-making and policy formulation in various problems and spatial scales. It actually represents a transition from a *top-down*, largely hierarchical, control- and command-based planning model, to a *bottom-up*, more "*human centric*" structure of decision-making processes, aiming at co-identifying problems and jointly setting up priorities; and cooperating in the elaboration of solutions and implementation of sustainable development strategies and related policy frameworks in order to realize them (Kanji and Greenwood 2001; McGinn 2001; Innes and Booher 2004; Stratigea 2015; Stratigea et al. 2015; Panagiotopoulou et al. 2016). It can also contribute to the collection of remarkable and multidimensional information, which emerges from the cooperation among a variety of actors within highly interactive environments; and can reveal different views, visions, desires, fears, etc. Such interaction, according to numerous researchers (Pereira and Quintana 2002; Puglisi and Marvin 2002; Mostert 2003; etc.), constitutes a major step for the *integration* of different opinions; increases awareness as to shared great challenges ahead; promotes mutual understanding and networking within societies; while it can result in new innovative knowledge production and synergies' creation, capable of coping with wicked problems.

The integration of spatial planning and decision-making processes with participatory approaches is perceived as an important step forward, so as views and expectations of various societal groups to be effectively embedded in the final planning outcome; and uncertainties relating to value systems' exploration and validity of decisions made to be overcome. Furthermore, it marks a transition from traditional consultation of planners with experts to consultation with a wide range of local actors (experts, citizens, local stakeholders, associations, institutions, etc.) that reflects the particular focus of participatory planning on "*... planning with the community rather than for the community*" (Pettit et al. 2007: 22.4).

The above described new ICT-enabled perspectives have pushed forward the growth of *participatory democracy* in urban planning, a transition that implies a more intense use of Web-based interaction among decision makers, planners and local communities. Strengthening participatory context in decision-making at the urban level has led to the current evolution of *spatial governance models*, applied to both urban and regional planning studies (Pereira and Quintana 2002; Zwirner and Berger 2008). Based on these models, new urban and regional planning processes are developed, which are characterized by the wide variety of ICT-enabled local stakeholders' engagement; and are serving different objectives and related outputs, in an effort to deal with *resource scarcity and sustainability goals* in largely wired environments.

3   Evolution of ICT-Enabled Participatory Planning— e-Planning and e-Participation

Rapid technological developments of recent years have driven remarkable changes that have had, and continue to have, broad ramifications from an economic, social, environmental and political point of view (Hackler 2006). More specifically, quickly evolving digitally-enabled environments have initiated *innovations* and *altered processes* in the political, technological, economic, environmental, cultural and social sceneries (Panagiotopoulou et al. 2016). Within these environments, new challenges have come to the forefront for decision makers and planners, a fact that was prophetically questioned early enough by Castells (1992) in his article "The World has Changed: Can Planning Change?"

In coping with wicked planning problems in highly complex and uncertain urban environments, the role of ICTs and their applications is nowadays highly appreciated mostly due to the effective *digital interaction* "*bridges*" these build among decision makers, planners and local societies; and the new potential for managing and visualizing *large spatial data sets*.

Spatial planning processes are particularly complex, combining information and data from different knowledge domains, which furthermore lack homogeneity (e.g. statistical data and spatial data); they are dynamic in nature; and, in general, it is hard enough to communicate these processes to less skilled stakeholders (Hansen and Prosperi 2005). Moreover, participation in spatial planning requires access to information that is strongly dominated by visual media in the form of *maps and images*, with textual description being an important subcomponent of such information (Hudson-Smith et al. 2002). Of great help in this respect is the maturity of GIS that allowed their extensive use beyond very technical environments. This has enhanced the potential for spatial data management and visualization in a GIS environment. Furthermore, Web developments have allowed *interactive Web-based GIS* exploitation as a bidirectional interactive approach (Hansen and Prosperi 2005) that can ensure equal access to information; render participation wider and more substantial due to the better grasping of spatial data and problems; create new perspectives for social inclusion; and strengthen democratic procedures that support efficiency of spatial decision-making (Stratigea 2015; Panagiotopoulou et al. 2016). Interactive visualization and (Web-)GIS applications can be adopted/used in order for various pieces of information to be presented in an understandable way; and the investigation of spatial relationships and problems to be enabled. This way, users' apprehension of a spatial planning problem can be increased, and thus opportunities for essential and value-adding *public participation* can be broadened (Panagiotopoulou et al. 2016).

Current developments towards a *smart city context* are expected to further strengthen *data-intensive* urban planning and policy, mainly emanating from the huge potential offered by the implantation of a "digital skin", i.e. sensors into urban

environments (Rabari and Storper 2014) that facilitates *quantitative data collection* on a variety of urban dimensions through networks of sensors. Such a wired environment will also enable the collection of an unprecedented amount of *qualitative data*, a fact that will be supported by the evolving new spirit of participation and the modern forms of digital interaction and crowdsourcing by a variety of actors, such as residents, governments, professionals and businesses, civil society organizations, etc. (Panagiotopoulou et al. 2016). This leads to a remarkable change in planning practice due to also the pervasive role of ICT-enabled e-Planning potential; and relates to the blurring of the discrete roles of planners and urban actors in respect of *information production and consumption* (Hudson and Smith 2002; Roch et al. 2012; Stratigea 2015; Panagiotopoulou et al. 2016), with the traditional role of planners as information producers to be gradually scaling back; while reinforcing the role of various actors in local communities as both producers and consumers—*prosumers*—of information (Wallin et al. 2010; Stratigea 2015; Stratigea et al. 2015).

Qualitative data collection, as many researchers claim will, in the near future, be further enhanced as a result of the currently experienced *participatory revolution* (Davidoff 1996; Fung and Wright 2001; Duxbury et al. 2015). This brings to the forefront the issue of *crowdsourcing* as "*…an online, distributed problem-solving and production model*" (Brabham 2008: 75); or a specific form of public (e-)participation in urban projects (Brabham 2009), serving a *twofold goal* namely to: acquire non-expert data and knowledge for feeding and therefore enriching the spatial planning process; and explore solutions to spatial planning problems and challenges, originating from the public's proposals. In the one or the other form, crowdsourcing can be used for conveying, from local communities to decision makers and planners, empirical knowledge and views on planning problems; identifying positive and negative dimensions of these problems regarding the way they are perceived by communities; rating these dimensions, etc., thus contributing to the *integration* of institutional (decision makers), scientific (planners) and empirical (communities) knowledge; but also *integration* of qualitative and quantitative data, shedding light on tangible and intangible (e.g. cultural) aspects of planning problems (Stratigea 2015; Panagiotopoulou et al. 2016).

The evolving ICT-enabled *interaction patterns* among decision makers, planners and local communities steer changes in the ways political voice and debate as well as decision-making processes for managing urban issues occur, with the ultimate goal of local communities' participation being the: empowerment and engagement of local actors; promotion of collaboration and conflicts' resolution; enhancement of accountability and transparency in governmental procedures; and support of more knowledgeable decision-making, governance and service delivery processes; while at the same time they play an important role in the achievement of resource optimization, sustainability and quality of life (Stratigea 2015; Panagiotopoulou et al. 2016). This interaction pattern seems to largely affect planning and governance aspects, whose effectiveness will be assessed on the basis of the strong and qualitative participation in decision-making they can promote.

The evolution of spatial planning nowadays demonstrates its adaptation to various broad developments as regards its theoretical basis, the tools and approaches adopted/utilized, but also its practice per se (Silva 2010), positively answering thus to the concern of Castells (1992). Today spatial planning, implemented in a globalized environment mainly characterized by uncertainty, complexity and, most importantly, the massive explosion of ICTs, has been pushed forward by effectively reading the new "signs" and taking a further step ahead towards the migration of participatory planning processes to the Web, setting the ground for the emerging *e-Planning* and *e-Participation* paradigms as valuable complements to classical face-to-face participatory approaches (Papadopoulou and Stratigea 2014; Panagiotopoulou et al. 2016). The recently evolving *e-Planning paradigm*, i.e. online spatial planning, focused on: the successful combination of participatory approaches and ICTs; and their incorporation in the (urban) planning discipline. This of course presupposes the existence of adequate technological and organizational infrastructures, in order for unhindered access of social groups to information and related planning services to be ensured, therefore highlighting the vital role of ICTs and their applications as well as the readiness of relating decision-making structures to follow such developments.

E-Planning constitutes a new challenge in the scientific field of spatial planning and "*... an instrument for collective action in the urban arena*" (Silva 2010:4). It can be perceived as an *interaction* but also a *social learning platform*, fulfilling two distinct purposes, namely (Silva 2010):

- facilitate all the work carried out during the various stages of the planning process, marking thus the transition towards *e-Planning*, which is assisted by GIS technologies for managing spatial data (Quan et al. 2001); and the Web for interaction and communication; and
- encourage and broaden public participation during the different steps of the planning process, contributing to the shaping of *participatory e-Planning*. Tools and technologies deployed at this stage offer public the possibility of e-Participation, while interactive Web maps are available so as to both improve information provision to the public and collect information or spatial data by the public (Craig et al. 2002; Goodchild 2007).

In such a context, use of the Web enables online communication among all parties involved, while GIS provide the spatial delineation of planning problems, their possible solutions as well as their impacts, enabling thus the better apprehension of problems at hand and their potential solutions. The above imply the broadening of e-Planning and e-Participation potential regarding all the three discrete planning stages, namely (Khakee 1998; Giaoutzi and Stratigea 2011):

- The *learning stage*: incorporating an in-depth analysis and understanding of the socio-economic and physical context—various layers in urban environments—within which the planning process is taking place; the identification and prioritization of problems inherent in this context; the delineation of respective goal and objectives; etc.

- The *evaluation stage*: structuring and evaluating alternative solutions so as the goal and objectives set to be achieved; assessing alternative solutions and their prioritization as to the goal and targets' fulfillment, together with the assessment of the policy framework which implements the dominant solution.
- The *implementation stage*: implementing the selected planning solution through specific policy options of the previous stage.

ICT-enabled tools and technologies that can be applied to e-Participation in the context of implementing the above planning stages are (Stratigea 2015):

- Tools and technologies for engaging citizens via the Web—e-Participation (applies to learning, evaluation and implementation planning stages).
- Tools and technologies for collecting and managing information, such as crowdsourcing, Web-GIS, etc. (learning stage).
- Tools and visualization technologies for presenting planning solutions and relating impacts, such as geo-visualization tools, Web-GIS, etc., setting the ground for collecting stakeholders' views (evaluation stage).
- Evaluation tools, such as multicriteria analysis for the online assessment and rating of the proposed alternatives by participants (evaluation stage).
- Tools and technologies for disseminating and communicating planning interventions and policies to citizens (implementation stage).

According to the aforementioned arguments, the implementation of e-Planning is closely related to the adoption and exploitation of ICTs in the various planning steps, from the information collection and elaboration stage to that of alternative solutions' building and evaluation, in order to come up with the optimal solution. At the same time, it is also closely related to the use of geospatial databases, which allow the spatial representation of the planning problems (Kubicek et al. 2007), in order for every participant to be fully aware of the problem under study. Finally, it requires an online service delivery system, a quite crucial issue for the successful implementation of e-Planning. Additionally participants, via an e-Planning platform, are given the chance to continuously monitor the progress of various planning steps, but also to be actively engaged in the planning process by expressing their opinions, expectations, aspirations etc.; and elaborating and/or approving planning decisions and relative policies (Shiode 2000; McGinn 2001).

Numerous researchers hold the opinion that the integration of Web and GIS technologies may significantly benefit spatial planning (Shiffer 1995; Kingston et al. 2000; etc.), since the participation of different societal groups is greatly broadened through e-Participation; and relative procedures are rendered "open", supporting this way transparency and liability of decision-making processes. Nevertheless, it should be noted that the use of tools and technologies for e-Participation and e-Planning does not relieve designers of a series of decisions and steps to be followed for the implementation of a participatory process. Such decisions relate to the planning of the participatory process per se, and are associated with a series of questions raised, such as "who benefits from the spatial planning process?", "what is the citizens' role in this process?" or "how

communication and interaction among different groups of participants can be enhanced?", "in which stage of the planning process should stakeholders be engaged", "what is the scope of participation", etc. (Stratigea 2015). According to Ferraz de Abreu (2002), for e-Participation and e-Planning, planners must make choices regarding:

- The participatory process per se, focusing on issues such as timing of communication with the public; engagement of the public before, during or after the planning process; delineation of the planning stages in which the public will be involved; type of information planners seek to collect; format of this information (e.g. textual or visual information, comments or sketches on a map, etc.); type of participation they pursue (passive or active), etc. Key questions in this context are: why public should be involved; who should be involved in order for the objectives set to be achieved; how will participants be engaged (choice of classical or online participation tools or combination of both); and when will the public be engaged.
- The type of technologies that will enable e-Participation and e-Planning on the basis of the objectives set and the special characteristics of these particular technologies; the technological and organizational infrastructures that support the entire process; but also the current communication pattern and standards of the specific society, within which e-Planning is implemented.

The tools and technologies that can be used for the implementation of e-Participation and e-Planning are briefly delineated in the following section.
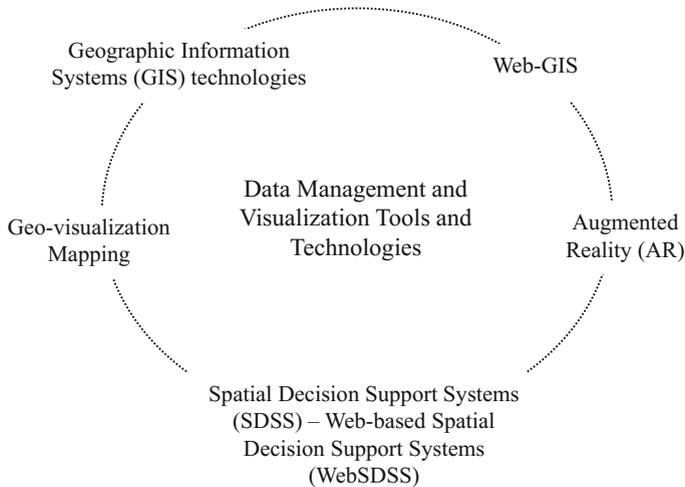
4 Tools and Technologies in Support of e-Participatory Spatial Planning in a Smart City Context

In recent years, the radical technological advances, the plethora of emerging applications as well as the new potential deriving from them for economic growth, environmental protection, social inclusion and quality of life, have broadly supported planners and policy makers in shaping a "smart" sustainable future for urban environments. Moreover, the advent of Web 2.0, which is described by Fuchs et al. (2010: 43) as "... *a medium for human communication*...", has offered users the opportunity to interact, communicate and collaborate with each other; and has rendered them creators of *user-generated content* in a *digital community*, broadening thus engagement and e-Participation. Additionally, planning "smart" entails the efficient management of *big data* (extreme volumes of various and complex data), as well as the incorporation of public involvement at the various stages of the spatial planning process, two pretty intriguing issues arising in modern planning exercises.

Taking the above into consideration, an imperative need for a wide variety of tools and technologies, capable of enhancing *data management* (collection, elaboration, analysis, visualization, etc.) and strengthening citizens and stakeholders' engagement, to be at the service of planners and decision makers is coming to the forefront. These can be adopted/used for supporting planners in (Stratigea et al. 2015):
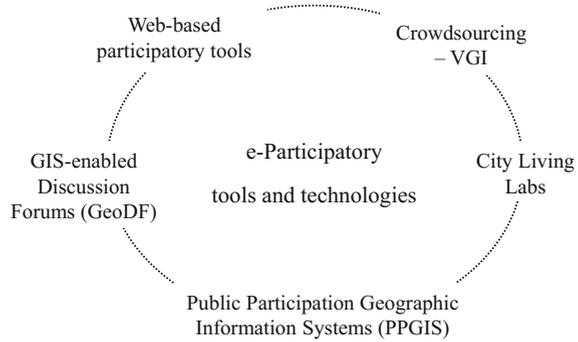
- perceiving cities' particular economic, societal and environmental attributes (urban context), but also their interrelationships;
- exploring, identifying and visualizing various (spatial) urban problems;
- communicating problems and disseminating potential solutions and policies to the recipients of the spatial planning effort (citizens, stakeholders, etc.), seeking at the same time building *consensus* and thus achieving a more effective and broadly accepted implementation of the planning outcome; and
- identifying policy priorities in each different urban environment in alignment with the prevailing value systems.

In this respect, this particular section focuses on the delineation of the *most significant ICT-enabled tools and technologies*, which are nowadays serving spatial planners' needs and aim at attaining sustainability objectives in urban contexts. These are divided into *two main categories* namely: data management and visualization tools and technologies; and e-participatory tools. A brief description of the main tools and technologies available as well as a number of respective smart city applications are presented in the following (Figs. 1 and 2).

Geographic Information
Systems (GIS) technologies

Web-GIS

Data Management and
Visualization Tools and
Technologies

Geo-visualization
Mapping

Augmented
Reality (AR)

Spatial Decision Support Systems
(SDSS) – Web-based Spatial
Decision Support Systems
(WebSDSS)

Fig. 1 Main data management and visualization tools and technologies

Fig. 2 Main tools and
technologies supporting
e-participation

Web-based
participatory tools

Crowdsourcing
– VGI

GIS-enabled
Discussion
Forums (GeoDF)

e-Participatory

tools and technologies

City Living
Labs

Public Participation Geographic
Information Systems (PPGIS)

4.1 Data Management and Visualization Tools and Technologies

Data management and visualization tools and technologies that are mostly
adopted/used are:

- *GIS technologies*: for surveying, visualizing, analyzing and communicating
  local problems and inefficiencies. A GIS integrates hardware, software and data
  for capturing, storing, elaborating, analyzing, managing and displaying all forms
  of geographically referenced information (Folger 2009). "*... GIS allows us to
  view, understand, question, interpret and visualize our world in ways that reveal
  relationships, patterns and trends in the form of maps, globes, reports, and
  charts*" (http://www.esri.com/). A GIS can also help planners to answer ques-
  tions and solve problems by looking at the data in a way that is quickly
  understood and easily shared (http://www.esri.com/).
- *Web-GIS*: refers to the integration of the Web with GIS, an important devel-
  opment which enhances user interactivity with maps and spatial analysis,
  expanding thus their potential for participating in decision-making processes.
  This integration is expected to rapidly escalate in the future, as highlighted by
  several researchers (Silva 2010; Craig et al. 2002); and has triggered further
  developments in the field of participatory planning.
- *Geo-visualization—Mapping*: mapping generally refers to the representation of
  data (e.g. spatial data) and information through the exploitation of their char-
  acteristics, their interrelations, and their relations with the geographical space
  and entities existing and taking action into this space. Specifically, in the case of
  spatial data and geographical information "*...a spatial data modeling process is
  adopted as a process of representing geographical reality*" (Goodchild 1992:
  401). Geo-visualization regards the visualization of geospatial as well as
  non-geographic information, while it also "*...serves two important functions,*

namely communication and analysis… It augments human visual ability in perceiving high complex structures, detecting, exploring and exploiting salient patterns" (Jiang and Li 2005: 3). In recent years, numerous *smart city applications*, adopting contemporary mapping and geo-visualization techniques, have been developed such as:

- *SmartMap Berlin*: fully mapping of the city of Berlin in a textured photo-realistic 3D format. The 3D model allows viewers to look at the city as it is now, as it once was, and as it might turn into in the future. Using 2D and 3D geodata, recent historical changes as well as future urban development projects can also be visualized (http://www.businesslocationcenter.de/smartmap-berlin).
- *Trento i-Scope Project*: concentrates on how cities can be reproduced using 3D Urban Information Models (UIM) in support of urban planning, city management and environmental protection. It is based on an open platform, enabling citizens to participate in data collection and enhancing Web-based services (http://crowdcity.com/).

- *Spatial Decision Support Systems (SDSS)—Web-based Spatial Decision Support Systems (WebSDSS)*: Spatial Decision Support Systems are interactive computer-based systems designed to support decision makers in solving complex spatial problems, such as site selection, urban planning, and routing (Sugumaran and Sugumaran 2007). SDSS incorporate Geographical Information Systems (GIS) functionalities (spatial data management, cartographic display, etc.), analytical modeling capabilities, flexible user interfaces, and complex spatial data structures (Goodchild 2000). A WebSDSS includes a Web-based GIS as a problem solver; and facilitates geographic data retrieval, display, and analysis (Sugumaran and Sugumaran 2007).
- *Augmented Reality (AR) Technology:* view of a physical, real-world environment, whose elements are supplemented by computer generated input (sound, video, graphics or GPS data). Stated otherwise, AR interfaces allow users to experience the real world; while at the same time virtual displays can be overlaid upon or composited with real locations and objects (Azuma 1997). *IssySpots* is a mobile augmented reality application that was developed in Issy-les-Moulineaux—France, which contains a directory of more than 500 places of interest (public transport, tourist attractions, companies, administrations, schools, parks, etc.) that are displayed in real time on the user's mobile according to his/her location, enabling that way inhabitants and visitors to *navigate* in the city. With this particular technology, inlays and juxtapositions of virtual objects and information in a sequence of images are made possible. Users have also the opportunity to switch from the 2D plan to a 3D visualization (http://www.issy.com/).

4.2   (e-)Participatory Tools and Technologies

When planning in complex and highly uncertain urban environments, the role of the public as a valuable and essential source of multidimensional information for developing successful alternative plans is greatly acknowledged. As participants can and should become contributors to plans affecting their lives and surroundings, it is important that the right framework as well as the necessary tools and technologies are put in place in order for a more effective and pervasive participation context to be supported, in alignment with the multi-agent and multi-perspective nature of planning and the need for broadening its scope.

Towards this end, information on a range of *tools and technologies* that can be used for strengthening public engagement in planning the future of smart cities is systematically presented in the following. The scope of this step is to support planners and decision makers in implementing participatory planning exercises, by providing a range of available options (tools and technologies), together with explanatory information and examples that will facilitate their choice. The options available, in this respect, have as follows:

- *Web-based participatory tools*: such tools can range from preference functions, wikis, chat rooms, blogs, mailing lists, and rating systems to voting mechanisms and online surveys. They offer various e-participation potentials, while they enhance interaction among different societal groups regarding the outcomes of the planning process. Emerging Web-based participatory tools can potentially be used in urban planning in order for the context to be enriched and better results of public participation exercises to be achieved (Kingston et al. 2000; Wilson 2008).

- *Crowdsourcing—VGI*: The term 'crowdsourcing' was coined by Jeff Howe in his article "The Rise of Crowdsourcing", appeared in *Wired* magazine (2006), and is described as "... *a new Web-based business model that harnesses the creative solutions of a distributed network of individuals through what amounts to an open call for proposals*". Later on, Brabham (2008:75) argued that "... *crowdsourcing is an online, distributed problem-solving and production model*". Despite the fact that a commonly accepted definition of the term does not yet exist, crowdsourcing reflects a problem-solving approach, which presupposes the involvement of the crowd and results in the selection or shaping of the optimal solution, through the collection of distributed knowledge (Surowiecki 2004). In this sense, crowdsourcing can be considered as a form of participatory process in order for solutions to specific problems to be developed, involving at the same time various participants with different expertise, knowledge backgrounds, opinions, ideas, etc. It should be noted that, despite the fact that crowdsourcing was introduced and developed in the business sector, it can be adopted/used as a specific form of public participation (e-participation) as

well, for the implementation of urban projects (Brabham 2009) in the sense that it takes advantage of "*non-expert*" *knowledge* so as to find solutions to spatial planning problems and challenges or to acquire data and knowledge that can feed and enrich the spatial planning process. Moreover, the so called *Volunteered Geographic Information (VGI)* constitutes a particular form of crowdsourcing and refers to the volunteered production and provision of geographic information by individuals. Goodchild (2007: 212) defines VGI as a "… *special case of the more general Web phenomenon of user-generated content*". The "*IJburg YOU decide!*" project, which was developed in IJburg neighborhood—Amsterdam, constitutes a distinguished example of the use of a crowdsourcing Web tool, which enables citizens of IJburg area to share a future vision of their neighborhood, with emphasis on energy and mobility aspects. To do so, inhabitants were asked to fill a brief questionnaire, regarding what they think of their neighborhood, how they would describe it and what are their ideas for making that more sustainable. Based on the feedback gained from citizens, an action plan for Amsterdam Smart City Project was created and implemented in IJburg area (http://amsterdamsmartcity.com/).

- *Public Participation Geographic Information Systems (PPGIS)*: refer to the involvement of non-expert stakeholders in the spatial planning process (Ghose 2007; Ramasubramanian 2010), by combining community participation and geographic information on various city aspects (Steinmann et al. 2004). In other words, they attempt to bring the academic practice of GIS and mapping to the local community, enabling that way citizens' participation in the planning process and effective management of their living environment. In a nutshell, the scope of PPGIS is the *empowerment and inclusion* of local and marginalized population in spatial planning and decision-making processes (see further details in the next chapter). PPGIS activity usually involves either community mapping and database development, outside the formal government processes; or seeks expansion and enhancement of public participation and community collaboration in governmental processes for e.g. environmental planning and management (Brown 2012). Such an indicative initiative was successfully launched in Barcelona via *Repara Ciudad* application, an Open Data Cities (ODC) PPGIS platform, mainly addressing environmental issues. The application allows citizens to report damages and incidents of the urban environment to the local administration. The initiative's aim is twofold: on the one hand it attempts to bring inhabitants and public authorities close together so as to strengthen their environmental co-responsibility; and on the other hand it contributes to the shaping of a more participatory, transparent and efficient public administration (Turiera and Cros 2013).
- *GIS enabled Discussion Forums (GeoDF)*: constitute a significant tool for conducting discussions among participants, who are involved in the spatial planning process. In this context, they enable citizens to express their opinions

on a range of spatial problems, by utilizing user-friendly Web mapping and analysis tools. In order communication, better understanding but also interaction among participants to be facilitated, GeoDF offer them the opportunity to express (submit) and share their views, as well as to raise issues, relevant to the particular spatial planning problem that concerns them; and thus initiate new discussions with the other parties involved. The dominant feature of GeoDF is the *geographical reference* of participants' comments, through the expression of their views with text messages, notes, but also sketches, annotations, etc. on a map. Additionally, in order dissemination of users' views to be more effective, the system offers the potential for storing and sharing, among other participants, the different map layers in which they intervene. Views and interventions of each single user (comments, sketches, annotations, etc.) are organized and presented in a way that facilitates their incorporation in the participatory process (Zhao and Coleman 2006). The *argumentation map prototype*, introduced by Rinner (2001) in Germany, constitutes an object-based model for geographically referenced discussions; and is built upon discussion contributions (argumentation elements) and geographic reference objects, which are independent from each other (Keßler et al. 2005). Discussion contributions are also classified by issues in chronological order, while their distribution is shown on a map (Tang et al. 2005).

- *City Living Labs*: user-centered, open-innovation ecosystems, operating in the city context, which integrate concurrent research and innovation processes within a *Public-Private-People Partnership* (Von Hippel 1986; Chesbrough 2003; Komninos 2006, 2009). Living labs, in this respect, can be considered as *experiential environments*, where users are immersed in a creative social space for exploring, designing, evaluating and refining their own future as well as the policies driving from the current state to the desired futures. An interesting example of City Living Labs is presented by the *Territorial Living Lab (TLL) Sicily* that aims at exploiting ICTs in order innovative means of participatory strategic co-planning and territorial self-governance to be developed, under the assumption that citizen co-responsibility and ownership, awareness of context and implications of choices and monitoring of the impacts of decisions taken, can together finally generate models for sustainable spatial development (http://www.openlivinglabs.eu/livinglab/tll-territorial-living-lab-sicilian-region).

Finally, it should be noted that, in most cases, a combination of tools and technologies can be exploited so as to achieve more efficient utilization of available resources and existing ICT infrastructures; and offer a wide range of access options regarding online participatory processes to the public, according to its communication standards. For example, voluntary provision of digital spatial information from citizens (VGI) may be embedded in a PPGIS system, where citizens participate in the production of the required information, possibly under experts' guidance (Tulloch 2008).

5 PPGIS for Community Empowerment in Spatial Planning

Participation in spatial planning demands information that is strongly dominated by visual media (3D representations, maps, images, etc.), since they provide a close representation of reality, with textual description being an important subcomponent (Hudson-Smith et al. 2002). Taking also into consideration that people perceive and understand the information they receive according to their own cultural and social experiences (Lewis and Sheppard 2006), the adoption of visual media is required, since they entail limited linguistic and cultural barriers compared to written or verbal messages (Steinitz 2010). In this respect, geographical visualization of space (urban, rural, regional areas, insular, etc.) is perceived as a significant means of communicating the different steps of the spatial planning process to the public and stakeholders, while it is also a powerful technique for engaging them in decision-making processes (Pettit et al. 2007; Warren-Kretzschmar and Von Haaren 2014). It should also be stressed that visualization techniques offer powerful enabling tools supporting different tasks in the various stages of a participatory spatial planning exercise. For example, it can be used during the in-depth analysis of the current state of the area under study, so as to trigger public's interest in the spatial planning problem concerned and/or provide a common basis for the exchange of indigenous information and knowledge. It can also be deployed during the alternative solutions' building process, since participants can use visualizations to illustrate planning solutions and collaboratively develop a *shared vision* for the future (Warren-Kretzschmar and Von Haaren 2014).

Despite the fact that traditional communication tools in spatial planning, such as static maps, diagrams and texts still constitute the most common media for diffusing and communicating information, these exhibit great limitations regarding their ability to convey a deeper spatial understanding to lay audiences (Tress and Tress 2003; Lewis and Sheppard 2006), mainly due to lack of interactivity with users. In this respect, interactive visualization techniques and Web-GIS applications can be adopted/used in order for various pieces of (spatial) information to be presented in a more understandable way; and the investigation of spatial relationships to be enabled. Consequently, users' awareness and apprehension of a spatial planning problem can be increased, and thus the opportunities for essential public participation can be broadened. Users may also contribute by providing additional data through crowdsourcing.

According to the aforementioned, the concept of *Public Participation GIS* has come to the forefront and focuses on (Rambaldi et al. 2006: 2):

> Community empowerment through measured, demand-drive, user-friendly and integrated applications of geospatial technologies…. It promotes interactive participation of stakeholders in generating and managing spatial information and it uses information about specific landscapes to facilitate broadly-based decision-making processes that support effective communication and community advocacy.

The development of such systems originates in the 90s (the term PPGIS was conceived in 1996 at the meeting of the National Center for Geographic Information and Analysis—NCGIA); and focuses on *bridging the gap* between public participation and technology, as well as integrating GIS technologies into participatory spatial planning (use of Web-GIS by lay people). Atzmanstorfer and Blaschke (2013) highlight that PPGIS, as an approach which strengthens citizens' empowerment and participation in spatial planning and decision-making in general, may become a substantial tool in support of Spatial Decision Support Systems (SDSS).

PPGIS constitute a Web-GIS platform used by citizens in the context of various participatory spatial planning exercises. They support online data collection and processing in order for new (spatial) knowledge, relevant to a specific planning problem, to be produced (Craig et al. 2002; Brown 2012). In a nutshell, they can be perceived as a set of methods, techniques and technologies that contribute to the integration and inclusion of indigenous knowledge and different views expressed by participants; and to their mapping on the spatial context to which these refer. In this sense, the enabling and promotion of online interaction and communication with citizens, incorporated in GIS technologies, constitutes a crucial step towards significantly broadening the e-Planning perspective in the context of participatory spatial planning; and supports the effective use by the public in contrast to the traditional use by the experts (Talen 2000; Ghose and Elwood 2003).

The generic methodology adopted and followed for carrying out a PPGIS exercise comprises three discrete stages (Mare Nostrum Project 2015) which are illustrated in Fig. 3. More specifically:

Stage 1: Identification of Participants - PPGIS Community The role of participants is of catalytic importance for both the planning process and its outcome. Thus, proper selection of participants is considered a critical factor. PPGIS community refers to the identification of the group of citizens and stakeholders who can participate in PPGIS exercises. A manifest answer to the question "Who should be involved in a participatory spatial planning project?" implies the need for a certain stakeholders' analysis, taking into consideration the goal and objectives of the planning problem at hand, its controversial nature, the spatial scale concerned etc. Various approaches for stakeholders' analysis can be encountered in the literature. What is important in this respect is that identification of relevant stakeholders has to take into consideration the basic principles of participation and more particularly (Bousset et al. 2005):

Fig. 3 Methodological steps for the implementation of a PPGIS project (*Source* Mare Nostrum Project 2015)

Identification of Participants - PPGIS Community → Collection of Data & Maps → Construction of an Online PPGIS
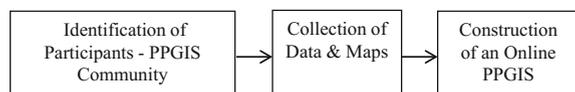
- *Inclusion*: Everyone should have equal opportunity to express his/her views and contribute to the formulation of solutions.
- *Relevance*: Anyone who is affected or can affect or can contribute to the planning process must be able to participate.

Moreover, since participants possess different levels of GIS and cartographic literacy, their appropriate training constitutes an integral part of this step.

Stage 2: Collection of Data and Maps During the preparation phase of PPGIS practice, maps or other visual media are assembled, while data need to be collected, elaborated, analyzed and visualized, in order participants to better understand and discuss the spatial problem under study. Apart from existing maps, it may be necessary to produce new ones, GIS layers or linked attribute data (Mare Nostrum Project 2015).

Stage 3: Construction of an Online PPGIS In order to enable and strengthen PPGIS community's interaction with spatial information, a Web-GIS platform is developed. Through the deployment of this platform, existing maps, GIS layers and attribute data are published online, and a user-friendly interface, where people can draw their own maps, is created. Participants are working on maps and data provided; and build further upon them, by adding their perspectives and local knowledge (Mare Nostrum Project 2015).

Deployment and use of PPGIS give citizens the opportunity to interact with the planning proposals via a visualized (maps) and interactive (online communication) way, which is not possible when following traditional participatory methods. At the same time, citizens' involvement can potentially result in the enrichment of spatial data managed by a GIS, which can introduce data and information related to the value system, local culture, history and tradition, etc., emanating from participants' views. Consequently, the final product is not just a spatial representation of the proposals and interventions derived from spatial planning per se, but a holistic proposal that embeds citizens' value system and principles in this spatial representation, thus serving the objectives of participatory planning (Stratigea 2015).

PPGIS applications may focus on:

- collecting data from various societal groups in order spatial planning ground to be enriched; and producing new maps that relate to the planning problem under study;
- broadening of citizens' empowerment and involvement in the spatial planning process, thus assigning them a more meaningful and active role.

A peculiar attribute of PPGIS practice is associated with the rendering of GIS technologies and systems available to the public (local and less privileged societal groups) for empowerment purposes. In this respect, their capacity to communicate, disseminate, generate, manage and use indigenous knowledge is enhanced; while also citizens' engagement/involvement in spatial planning decision-making is respectively broadened. Finally, PPGIS and can be adopted/used for various purposes such as (Rambaldi et al. 2006):

- conflict management among various local groups and between communities and local authorities regarding access, exploitation, control and allocation of resources;
- collaborative research;
- collaborative resource use planning and management;
- preservation of intangible cultural heritage;
- identity and vision building by local groups;
- transparent and consensual governance in spatial decision-making;
- awareness, education and social learning for new generations; and
- promotion of equity with regards to ethnicity, culture, gender, environmental justice and hazard mitigation, etc.

It is worth noting that apart from the typical PPGIS Web applications, these can be implemented in a conventional way also, through interpersonal communication with users—groups (Craig et al. 2002); while PPGIS may also constitute a complement to traditional participation methods (Steinmann et al. 2004).

6 Discussion

The evolution of Web and "cyber space" has set the ground for the illimitable knowledge diffusion, the promotion of innovation, the online problem solving and the dynamic interaction among people. ICTs have penetrated almost all aspects of modern globalized world, acting as integrating and enabling technologies (Caperna 2010) and establishing a new digital era, where "...*individuals are required to use a growing variety of technical, cognitive and sociological skills in order to perform tasks and solve problems in digital environments*" (Eshet-Alkai 2004: 93).

The incorporation of technological developments and their applications in spatial planning has brought to the forefront the concepts of *e-Planning* and *e-Participation*. These concepts are constantly gaining ground, since they are perceived as approaches that can fully convey the whole spatial planning process to the Web, thus facilitating public participation and attracting the interest of a wide range of participants. In this respect, they are considered as means to the expansion of the planning knowledge base, but also to the exploration of the range of different views expressed by various societal groups in order these views to be embedded into the final planning outcome. As such, they contribute to the upgrading of the planning process per se, via the broadening of participatory dimension and thus the bettering of the final planning product (Papadopoulou and Stratigea 2014).

Literature review shows that a significant range of mature tools and technologies is already available for fulfilling the objectives of participatory e-Planning and e-Participation. However, an important and noteworthy disproportion between theoretical contributions to the fields of e-Planning and e-Participation and maturity relating to tools and technologies on the one hand, and number of empirical applications on the other is observed (Geertman 2002; Campagna and

Deplano 2004), which constitutes a major issue for discussion and debate; while the impacts on broadening public e-Participation still remain a matter of sociological investigation.

Some initial attempts to interpret the above disproportion concluded that the technological evolution is a necessary but not sufficient condition for the implementation of online *participatory and geospatial technologies*; while experience shows that their adoption/use still requires the tackling of numerous intriguing issues arising, which are associated with technical, political, cultural and social aspects. As such can be mentioned (Kubicek and Westholm 2005; Macintosh 2006):

- The need for expanding ICT applications in spatial planning, so as transition from mostly pilot applications currently implemented to their widespread use to be achieved, emphasizing thus their adding value in planning.
- The technological dimension for public participation purposes should be further emphasized, in order for participatory e-Planning to be facilitated and spread; and user-friendly interfaces, for interaction and collaboration, to be developed.
- The requirement for reliable, discrete and easily communicated information representation and effective management of participants' contribution.
- The necessity for integrating the technological potentials and their applications in political processes and decision makers' organizational structures.
- The assessment of e-participatory processes' outcomes, which can significantly contribute to the improvement of their technological, organizational, political, social, etc. dimension.

Finally, an important disadvantage observed, regards the assessment of the results of e-Participation and e-Planning, in the sense that evaluation criteria and relevant indicators, on the basis of which the *effectiveness* of their implementation can be assessed, should be defined; and through them the *value added* by that type of planning exercises should be delineated.

Effectively dealing with the above aspects is quite important in an information-intensive era, as the concept of smart cities, apart from a new digitally-enabled urban management paradigm for reaching a competitive and sustainable urban edge, is mainly an evolving *collaborative paradigm*, where sophisticated ICT infrastructures and respective applications can considerably broaden communities' engagement; strengthen interaction and synergies' creation among various actors (policy and decision makers, planners, stakeholders, citizens, scientists, etc.); and promote a cooperative approach, necessary for coping with great challenges ahead in a contemporary city contexts. Such a paradigm can support a user-driven and human-centric tackling of smart cities' planning in the evolving "Urban Age", rendering thus planning a powerful discipline for increasing awareness, building of consensus and responsibility. Public Participation as "...*the involvement in knowledge production and/or decision-making of those involved in, affected by, knowledgeable of, or having relevant expertise or experience on the issue at stake*" (Van Asselt and Rijkens-Klomp 2002: 168), as well as

digitally-enabled tools and technologies that can broaden potential of communities to actively engage in coping with new challenges is of crucial importance in this respect. This holds true for the Mediterranean people and small and medium-sized cities in this area as well; and represents a turn back (or a path forward) to participatory democracy, exercised in this region for centuries; but also a promising option for finding ways to deal with Mediterranean hot spot dimensions.

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