Spatial Tools and ppWebGIS Platforms for Sustainable Urban Development and Climate Change Adaptation

Participatory Planning in Urban Areas with Special Conditions

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Abstract. In the last decades, a shift towards more democratic, participatory processes has occurred, rooted in the need to address environmental problems and climate change threats. Moreover, these participatory processes have been increasingly required in today's spatial plans, strategies, and studies, for example, in Sustainable Urban Mobility Plans, Urban Climate Change Adaptation and Resilience Plans, and Sustainable Development Plans. In this context, academia and industry have built various public participation web-based solutions (ppWebGIS) and other geospatial participation tools to facilitate participatory procedures and support and inform the participants (planners, policymakers, citizens, etc.) towards spatial decision-making.

However, despite the recent advancements in methodological and technological participatory geospatial tools, they are weak in addressing the complex issues found in "outlier" urban areas, i.e., areas with challenging conditions and characteristics. This paper introduces a comprehensive methodological framework for participatory spatial planning that conceptualizes and utilizes geospatial tools and platforms to address the challenges and opportunities in areas with special conditions. As part of an ongoing research program, the paper's main contribution is to provide methodological innovation for participatory spatial planning in areas with special conditions through conceptualizing and implementing participatory geospatial tools to solve complex and multifactorial spatial problems.

Keywords: urban planning · participatory planning · ppWebGIS · ppGIS · geospatial · sustainable development · climate change

1 Introduction

Geographical Information Systems (GIS) can support multicriteria analysis through structured procedures for spatial decision-making [1, 2]. When the involvement of citizens, stakeholders, and experts is decisive in decision-making, then the concept of ppGIS is most appropriate. Public Participation Geographic Information Systems (PPGIS) was

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introduced in 1996 during the National Centre for Geographic Information and Analysis (NCGIA) meeting. The term ppGIS appears in the U.S. and is mainly used in developed countries. PGIS is often used to describe participatory design approaches in developing countries' rural areas [3].

In the context of the United Nations' Sustainable Development Goals (SDGs)[1], UN-Habitat[2], the new European Climate Change Adaptation Strategy[3], the new Horizon Missions[4], and the New European Bauhaus initiative[5], the role of advances and multi-level participation is crucial (Table 1). This approach recognizes that effective planning and design requires a collaborative and inclusive process that involves all stakeholders and considers their diverse perspectives and needs.

Table 1. Participation is an essential element in different global approaches

Approach	Participation elements
Sustainable Development Goals (SDGs)	• engaging local communities and marginalized groups to ensure that their needs and aspirations are fully considered • partnerships between governments, civil society, and the private sector in achieving the SDGs
UN-Habitat	• empowering communities and involving them in decision-making processes that affect their lives • recognizes the need to address social exclusion and inequality issues, particularly in urban areas, to promote sustainable development and social justice
Climate Adaptation and Resilience	• engaging stakeholders in developing and implementing strategies to address climate change's impacts • requires a collaborative and inclusive process that involves all stakeholders, including vulnerable populations
Horizon missions	• address some of society's significant challenges, such as climate change, energy, and health • emphasize the importance of involving stakeholders in co-creating and implementing solutions to these challenges
New European Bauhaus	• collaborative, multidisciplinary, multi-stakeholders participation, co-design of transformative projects, initiatives, and measures

[1] https://sdgs.un.org/goals.
[2] https://unhabitat.org/.
[3] https://climate.ec.europa.eu/eu-action/adaptation-climate-change/eu-adaptation-strategy_en.
[4] https://research-and-innovation.ec.europa.eu/funding/funding-opportunities/funding-programmes-and-open-calls/horizon-europe/eu-missions-horizon-europe_en.
[5] https://new-european-bauhaus.europa.eu/index_en.

This paper intends to present a concept and methodology for participatory spatial planning that employs geospatial tools and participatory platforms to tackle urban areas' unique challenges and possibilities. As an ongoing research program element, the paper's primary contribution lies in its innovative methodology and technology for participatory spatial planning in areas with special conditions through conceptualizing and implementing participatory geospatial tools to solve complex and multifactorial spatial problems.

1.1 Background

This paper is part of the research project "eLEONAS ppWebGIS: PARTICIPATORY PLANNING PLATFORM FOR SUSTAINABLE DEVELOPMENT". The main objective of "eLEONAS ppWebGIS" research project is to design and develop participatory design processes and tools to support spatial decision-making for development, planning, and intervention in urban areas presenting specific challenges and/or potentials. It aims to introduce participatory design in the Integrated Planning for Sustainable Development [4] as a "system" useful for multiple spatial scales and planning applications that directly address public needs.

1.2 Literature Overview and Trends in Public Participation Platforms and Tools

In the last decade, the academy and industry have built numerous digital participation tools and ppWebGIS solutions to support spatial decision-making [5]. The ppWebGIS solutions cover different needs and appear as autonomous tools, plugins, or integrated platforms. An increased interest is noted in strategic, urban, and environmental planning, especially regarding sustainable development, as well as climate change adaptation and resilience.

A semi-systematic approach [6] is employed to explore the progress of public participation tools and platforms in the urban context. Primarily, the database Scopus (https://www.scopus.com/) is used, updated on 20 April 2023. An iteration of three queries to refine the results and highlight the trends in research. All research queries are searched into the papers' titles, abstracts, and keywords. All languages, document types, years, and countries are included. Three subject areas are excluded (Biochemistry, Genetics and Molecular Biology; Medicine; Pharmacology, Toxicology and Pharmaceutics).

The first query[6] explores the presence of public participation web-platforms, integrated with GIS technologies. The result shows **842** documents. As shown in Fig. 1, research interest is increasing, with a maximum in 2019 (75/842 document results). Regarding subject areas, Social science, Environmental science, Computer science, and Earth and Planetary Sciences hold most of the related research.

[6] TITLE-ABS-KEY (pp*web*gis OR ppgis OR pgis OR soft*gis) AND (EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "PHAR")).

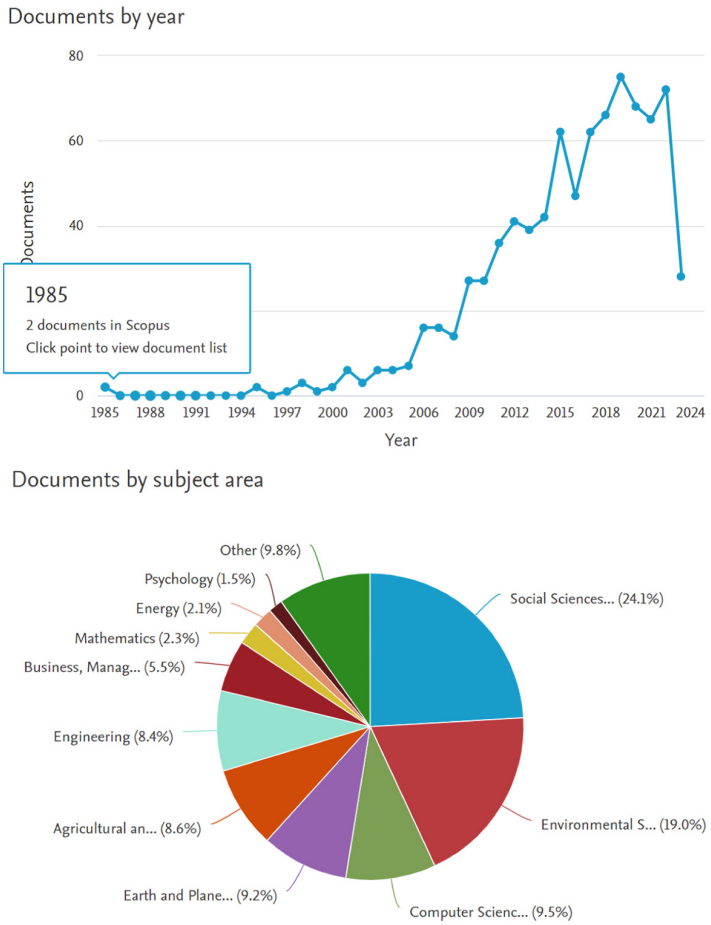

Fig. 1. Progress of research concerning public participation WebGIS platforms, across time and subject areas, through Scopus

The second[7] round of research explores the focus of the first round results in the urban context. The result shows **230** documents. The final[8] refinement search results to only **31** documents from 842, discuss public participation platforms and tools integrated with WebGIS technologies, under the concept of climate change, resilience, or sustainability, in the urban context. As shown in Fig. 2, almost 60% have been published in the last five years; the COVID 19 restrictions impact the field [7, 8]; an ascending number

[7] (TITLE-ABS-KEY (pp*web*gis OR ppgis OR pgis OR soft*gis)) AND (TITLE-ABS-KEY (urban OR city OR cities)) AND (EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "PHAR")).

[8] (TITLE-ABS-KEY (pp*web*gis OR ppgis OR pgis OR soft*gis)) AND (TITLE-ABS-KEY (urban OR city OR cities)) AND (TITLE-ABS-KEY ("climate change*" OR "resilien*" OR sustainabl*)) AND (EXCLUDE (SUBJAREA, "BIOC") OR EXCLUDE (SUBJAREA, "MEDI") OR EXCLUDE (SUBJAREA, "PHAR")).

of projects explore urban green ecosystem services, whereas 2020 concentrates the maximum number of documents.

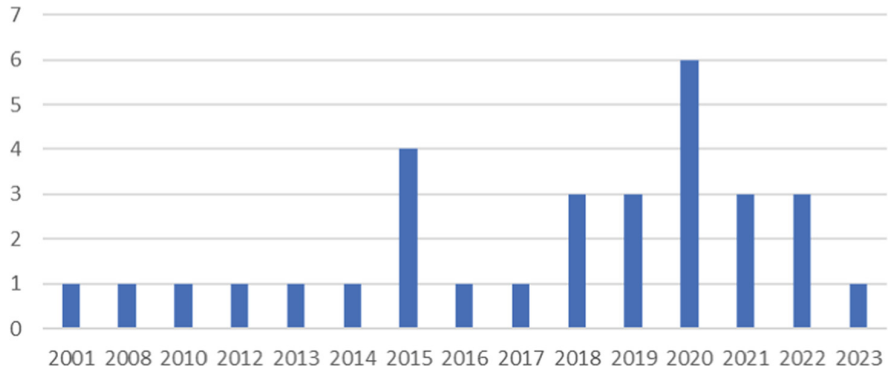

Fig. 2. Documents per year (31 selected by the final query in the Scopus database)

We analyzed the content of the 31 chosen documents related to the different thematic areas relevant to Integrated Planning for Sustainable Development. The eight thematic areas are:

1. Sustainability
2. Adaptation to climate change, risk, or resilience
3. Mobility
4. Ecosystem services
5. Urban Green Spaces
6. Landscape
7. Smart
8. Waste management

Four documents are not included in the following table because they did not meet the criteria of thematic relevance. The remaining 27 documents are presented in Table 2 per thematic area.

Different scales are presented in the selected documents, city [8–10, 16, 22, 28], neighborhood [7, 20, 29, 32], street [11], or other local scales [7, 20, 29]. Most of the documents are related to surveys or spatial questionnaires and ascertain that most cases are limited to low engagement levels (inform or consult) [7–9, 11, 16, 21, 22, 28, 29]. Lastly, an interested critic is deployed [32] to discuss the "elitist and undemocratic" view of ppGIS technologies, exploring contradictory results, empowerment, and dependency.

Table 2. Documents per thematic area

Thematic areas	Documents
Sustainability	[9–15]
Adaptation to climate change, risk or resilience	[12, 16–20]
Mobility	[7, 9, 21–23]
Ecosystem services	[8, 24–27]
Urban Green Spaces	[8, 22, 28, 29]
Landscape	[11, 24, 30]
Smart	[10, 14]
Waste management	[31]

2 Conceptual and Methodological Framework

Planners, consultants, and policymakers use participatory planning combined with WebGIS platforms all over the world to cover the needs of:

- different planning phases [33]
- different levels of engagement [34]
- various methods and technics of public participation [35]

Even though the market offers many solutions regarding basic participatory planning procedures[9], like collaborative whiteboards[10], and teleconference platforms[11], in this paper, we focus on the spatial and online aspects of participatory tools[12,13]. More specifically, we focus on ppWebGIS platforms and tools covering participatory needs of Sustainable Development plans as well as Climate Change Adaptation and Resilience plans and strategies. These emerging and urgent aspects of planning include public and expert participation as fundamental pillars and data-driven spatial decisions (big data).

Drafting Sustainable Development/Climate Change Adaptation and Resilience Plans and Strategies (see Fig. 3) includes different scales (e.g., neighborhood, local, city, regional, national) at different timelines (e.g., months or years until implementation). Those Action Plans and Strategies propose and aim at different goals, depending on the planning phases (assessment, draft, implementation, revision). To achieve those goals, the Action Plan/Strategy describes several projects or actions, in diverse and complementary thematic areas, usually in different spatial units. These plans are inter-disciplinary and trans-disciplinary high complexity problems and need advanced

[9] Padlet (https://padlet.com/), Google docs (https://www.google.com/docs/about/).

[10] Miro (https://miro.com/), Mural (https://www.mural.co/).

[11] Zoom (https://zoom.us/).

[12] GISCloud (https://www.giscloud.com/), Maptionnaire (https://maptionnaire.com), ArcGIS online (https://www.arcgis.com/index.html).

[13] ppCITY (https://ppcity.getmap.gr/dev/), participatory LAB (https://platform.participatorylab.org/; https://www.participatorylab.org/).

participation procedures supported by big data (e.g., geodata, climate, Copernicus, census).

To cover those advanced participation needs, planners and consultants use different digital tools, depending on their and the participants' digital skills, according to the project requirements, methods, and technics used. Public participation WebGIS platforms can facilitate multiple users (e.g., experts, stakeholders, the general public, targeted audience), more than the actual numbers to approach through physical meetings. Also, it can easily facilitate procedures, like the Delphi method, that demand several iterations from the participants, usually from experts, to support prediction, prioritization, planning, and generally spatial decision-making.

At the same time, ppWebGIS offers the opportunity to consult and include complex and big geospatial data (e.g., IoT, sensors, city planning datasets, Copernicus data, and many more) during the participatory procedures. Finally, the quick and reliable ways to analyze and summarize results and to export and use the participants' input as another geospatial layer in spatial analysis make the procedure very powerful.

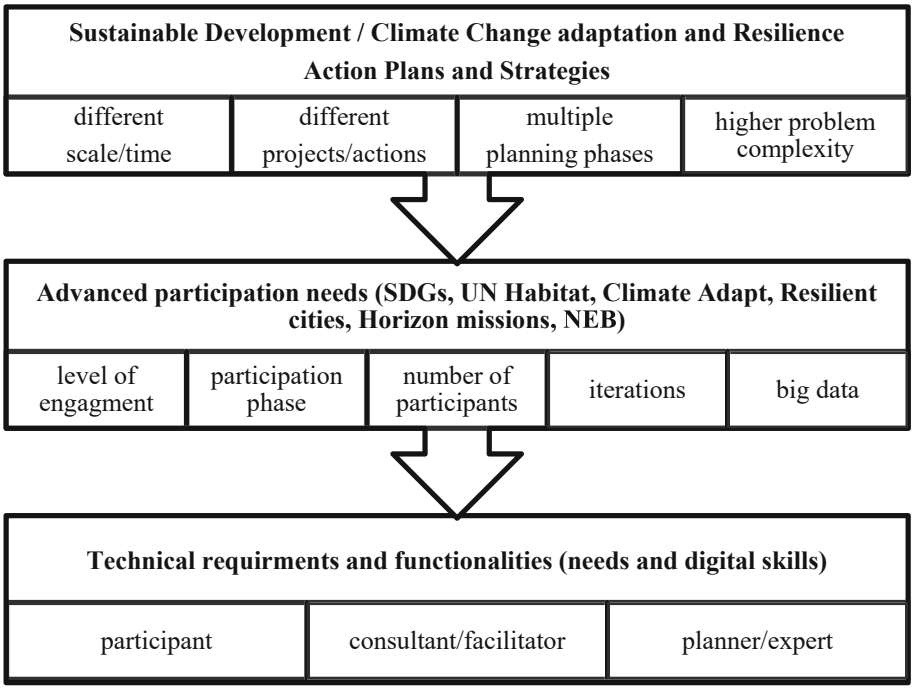

Fig. 3. Advanced participatory needs of Sustainable Development/Climate Change Adaptation and Resilience Action Plans and Strategies

The appropriate functional requirements focus on the three main groups involved in the process **a.** the participants with their diversity, **b.** the consultant/facilitator including the local authority **c.** the interdisciplinary team of planners/experts. The functional

requirements are approached step by step by planners and consultants, considering the different participant profiles.

In this context, a significant contribution of this paper is that it introduces a comprehensive methodological framework suitable for urban areas with special conditions but, more importantly, appropriate for different participatory planning applications (i.e., spatial planning, climate change adaptation, and cultural heritage sustainability). The developed methodological framework is structured in the following steps:

- **Investigation, management, and exploratory analysis of available secondary data**; to establish a baseline knowledge of AoI's characteristics and challenges, but more importantly, to identify the information gaps of the secondary data
- **Fieldwork for primary data collection**; to acquire the required detailed knowledge for the Area of Interest, which is key for participatory planning.
- **Analysis of the existing situation of the Area of Interest**; resulting in a comprehensive report describing the characteristics, needs, and challenges of the area of interest, formulating specific questions and objectives as input for the participatory procedures.
- **Participatory procedures**; relevant to different participatory planning applications and multi-level participation of experts, policymakers, stakeholders, and the public.
- **Scenarios and Alternatives**, the different scenarios and alternatives are visualized and included in a WebGIS environment facilitating the participation of various stakeholders.
- **Final consultation, community activation, and engagement**; which refers to innovative tools and methods for community activation and engagement (digital narratives, Location Based Social Network, and Phydigital path.

Table 3 describes the tools developed during the eLeonas project for each methodological step.

The aim is to introduce participatory planning in the **Integrated Planning for Sustainable Development** as a sub-system of it that can deliver on multiple scales while responding directly to public needs. Participatory processes that are emphasized respond to the following design/public needs:

- **Prediction**, where the involvement of experts is critical to the best possible approach and uncertainty reduction.
- **Planning**, where the involvement of multiple stakeholders is vital for the success of development and spatial planning.
- **Prioritization** (risks, measures, and actions), where the involvement of the general public, specialists, and other stakeholders (e.g., policymakers) determines the effectiveness of the proposed interventions.

3 Pilot Area - eLeonas Research Project

Eleonas is an urban area of Athens (see Fig. 4) in a strategic position between the capital city of Athens and the port city of Piraeus. It is intersected by important regional transport infrastructure and thus is a central transport hub for metropolitan Athens. It concentrates a multitude of -often contrasting- uses, functions, and activities such as

Table 3. Description of tools developed for each methodological step

Steps	Tools
Investigation, management, and exploratory analysis of available secondary data	• Geospatial database for storing and managing the data of each participatory planning application (satellite data, vector, tabular data): - Utilization of available open data sources - Utilization of proprietary and commercial datasets - Products from desk research • Project Repository, library (CKAN), for making project data available as open (in the cases that the existing license of the data permits it)
Fieldwork for primary data collection	• Mobile devices (cameras, smartphones, tablets) for fieldwork data collection: - Data collection via 360° spheres - Data collection via thermal camera and wearables - Digital geospatial tools for collecting primary data by filling digital forms (street audits, questionnaires, etc.) • Management and visualization of fieldwork data in a WebGIS environment, with the development of new functionalities for: - managing and visualizing 360° spheres and paths - crowd-sensed data from wearables - georeferenced fieldwork data
Analysis of the existing situation of the Area of Interest	• Development of open-source QGIS plugins as spatial analysis tools regarding: - implementation of various geo-visualization alternatives - custom-made and editable models of spatial analysis • Geo-visualization of the results in WebGIS

(*continued*)

Table 3. (*continued*)

Steps	Tools
Participatory procedures	• Multi-level participation of experts, policymakers, stakeholders, and the public • In a WebGIS environment, the following participatory tools are conceptualized and developed: - Questionnaires: Spatial and non-spatial - Spatial SWOT/PESTLE - Spatial Delphi - Spatial Shang - Pairwise comparison and other relevant methods
Scenarios and Alternatives	• Development as WebGIS functionalities: - Visualization of the analyzed data and relevant Key Performance Indicators (geoKPIs) - Visualization of the different scenarios and alternatives - Comments, "likes," and rating via the online desktop application and smartphone - Visualization of the adaptive capacity to climate change
Final consultation, community activation, and engagement	• Development of Location Based Social Network (LBSN) & Phydigital (Φ-gital) path

residence (formal and informal), industrial uses, logistics, higher education, and urban green. More specifically, logistics is the most prevalent use, followed by industrial uses, and to a lesser extent warehouses. Also, a substantial part of Eleonas is undeveloped land without use, while the residences are limited and concentrated in its northern part. This plethora of layers, identities, and stakeholders constitute Eleonas an ideal case study to conceptualize, develop and pilot a research approach for participatory spatial planning applicable to urban areas with special challenges and opportunities.

Within the eLeonas research project, an online participatory design platform for sustainable development is designed and developed where the user will find tools and methodologies for environmental, developmental, and spatial participatory planning. The platform is created based on innovative technologies and tools, namely:

- Spatial Data Organization, Analysis, and Management (ppWebGIS).
- Participatory planning tools embedded in the geospatial platform (Spatial questionnaire, Spatial SWOT/PESTLE, Spatial Delphi/Shang Method, and other Group Judgment technics) [36, 37].
- Collective awareness, IoT, and social networking tools.

The framework will be tested around three pilot applications (climate change adaptation, sustainable spatial planning, and cultural heritage vulnerability) in Eleonas, Athens (Greece). The tools and supporting toolboxes created can be implemented in other

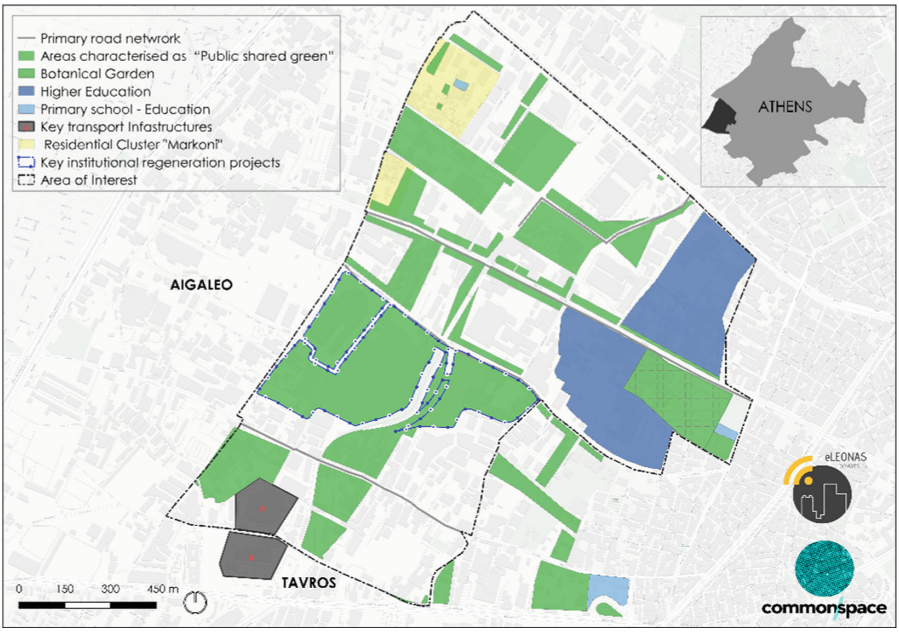

Fig. 4. Location of pilot area Eleonas, Athens (Greece)

regions with similar characteristics. It is essential to test new tools, integrations, and platforms with (almost) real-life pilots (Fig. 5).

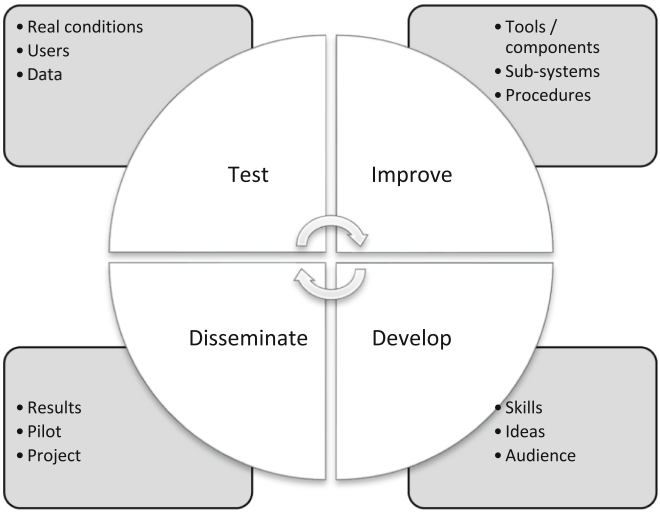

Fig. 5. The importance of real-life pilot cases for ICT research projects

This way, the research can be tested in real conditions, with the actual target group of users and the appropriate volume and complexity of data. Furthermore, the research team, along with the technical partners, can effectively improve tools and components of the digital solution, sub-systems, and procedures, especially participatory ones. This approach leads to the developing skills of the interdisciplinary team, the participants, and the interested parties. Also, to develop new ideas and to expand the audience. Finally, real-life pilots result in better dissemination and exploitation of the results, the project as a whole, and the research outputs.

4 Conclusions

According to the literature [3, 38, 39] and our experience and expertise, the main categories of participatory platforms and tools mainly support procedures of:

- Common vision
- Collective mapping
- Collective planning (or design)
- Expert knowledge (multi-stakeholders)
- Public awareness and final consultation (including scenario)

In addition, there is a need for expert judgment advanced features, at least for the main technics, (spatial) SWOT/PESTLE, (spatial) Delphi/Swang, and Pairwise comparison. Following, in Table 4, are presented the necessary functionalities and integrations.

For the tools to be inclusive, it is necessary to be well-responsive to mobile devices (android and iPhone). Safety of personal data and simplicity are key elements, especially when working with kids.

This paper presents the conceptualization and methodological development of the formal and informal functional requirements of the various ppWebGIS tools developed as part of "eLEONAS ppWebGIS" project. Employs innovative methodological and technological solutions to collect quantitative and qualitative data from the field. Conceptualizes and implements ppWebGIS tools to facilitate advanced participatory procedures (e.g., spatial SWOT/PESTLE, focus groups) tested and assessed for an area with special challenges and characteristics. Further research in this area could focus on implementing and assessing the developed conceptual and methodological framework in other instances to ensure that it fits the needs of spatial planning procedures in diverse spatial and cultural contexts.

Table 4. Functionalities and integrations

Functionalities and integrations	Description & notes
User's registration	Register by themselves or through an e-mail list. Provide statistical analysis—anonymous answers for minors or Expert judgment technics
Profile	"Consultation profile", characteristics for the specific consultation round or the thematic area. Ability to filter or weight the opinion based on the profile
Spatial questionnaire	All question types (i.e., text, multiple, radio button), including Likert, "more than", and image selection
	Answers' format Non-spatial or with geometry (point, line, polygon, Select from predefined features)
Group/expert judgment	(spatial) SWOT/PESTLE, (spatial) Delphi/Swang, Pairwise comparison
	Calculate consensus indicators, during Expert Judgment processes
Supporting material	Supported documents Library, collections, external URL
	Supporting maps, various basemap
Interaction	Voting/Like, Comments, Forum
Analysis	Basic statistical and spatial analysis during and after the participatory process
Visualization	Visualization of results during (preview) and after (final) the participatory process. Publish or hide
Export	Export results as maps, report, csv, json, or other
Integrations	Embed on online forms (i.e., google form, jotform, lime)
	Integrate into whiteboards (i.e., Miro, Mural)
	Integrate into teleconference platforms (i.e., zoom)

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Authors' Contributions. Mougiakou E. devised the main conceptual idea, conceived the methodological framework and steps, and selected methods and tools. In collaboration with Tsadari S. conceived the participatory approach of the eLeonas research project. All authors contributed to the drafting of the document and the figures. Mougiakou E. prepared the final text, tables,

and figures included in this publication. All authors provided feedback and reviewed the final manuscript.

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