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The Future of Civic Technologies for the Involvement of Citizens in Urban Planning: 3D Urban Participatory e-Planning in the Spotlight

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par

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Now comes the time to write the hardest section of the Ph.D.

It is difficult because we all know that it is the section that will be the most read and because I met and am thankful to so many people during this adventure. It will be difficult to name all of you.

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Abstract

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Problem. The development of sustainable urban projects is crucial to address the challenges of the growing population living in cities. Facing complex decision-making and increasing expectation from the population, local institutions are gradually open (and also compelled by law) to share their power with urban dwellers. However, the engagement methods designed by the authorities are not always adequate, leading to a lack of representativeness, bias, participation fatigue, poor inclusivity, or strong opposition. Since 2008, the development of Civic Technologies has attempted to create new modes of public engagement relying on digital solutions in order to improve the dialogue between the citizens and the authorities.

Goals. This digital revolution creates a flourishing number of new means to involve the population in urban planning. In the scope of this thesis, I aim to investigate one of these means: 3D urban participatory e-planning. This research has two main objectives: establishing guidelines to facilitate their design and application and assessing opportunities to adopt 3D mediums in current participatory practices.

Results. The findings presented in this thesis broaden the knowledge foundation of urban participatory e-planning by introducing a common vocabulary and crystallizing concepts, which support the evaluation of current tools. This theoretical structure explores participatory approaches through different components such as the urban project, the participatory process, and the selected interactive medium, but first and foremost, the affected participants. These stakeholders have a crucial role in all the applied approaches. Therefore, I question their connection with the (3D) medium in terms of access and cognition. First, I suggest an access evaluation framework, based on seven dimensions, which aspires to assist the local authorities in adopting a medium according to the access conditions of the target public to the participatory session. Second, I design an online user study that investigates how participants manipulate a virtual geographic environment, i.e., 3D tools. This study suggests that typical participatory setups do not stimulate active participation. Facing these findings, I present recommendations for the design of 3D urban participatory e-planning tools. These guidelines mention the personalization of the user experience combined with affordances, thus lowering the cost of use and improving user-friendliness. The last component of my research explores the design of successive prototypes based on a virtual globe, which was discussed with local authorities and urban experts. The gradual maturation of the prototypes leads to the introduction of a simplified approach to actively involve the population in planning processes: the guerrilla participation concept.

Conclusions. This thesis offers an extended analysis of 3D urban participatory e-planning by questioning the essential relations between this medium and the diverse aspects of citizen involvement approaches. This research, addressed to practitioners, officials, experts, and fellow researchers deliver crucial tools to enhance the design of 3D platforms. An improved design can promote the population's involvement in urban projects, leading to more inclusive participation, enhancing the legitimacy of decision-making, and ultimately driving a better, more sustainable development of the cities.

Keywords. Urban participatory e-planning, Civic Tech, participatory sciences, citizen engagement, 3D, Virtual geographic environment, Virtual Globe, public participatory GIS.

Résumé

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Problème. Le développement durable de projets urbains est crucial pour répondre aux défis liés à une population toujours plus importante vivant dans les villes. Face à la complexité des processus décisionnels et à la nécessité de créer des projets de plus en plus ambitieux, les institutions locales partagent progressivement leur pouvoir de décision avec la population, ces dernières sont aussi contraintes par un cadre légal. Cependant, les approches participatives conçues par les autorités ne sont pas toujours adéquates, ce qui peut entraîner un manque de représentativité, des biais, une lassitude de la participation, une faible inclusivité ou une forte opposition. Depuis 2008, le développement des technologies civiques (Civic Tech) tente de créer de nouveaux modes d'engagement du public reposant sur des solutions numériques afin d'améliorer le dialogue entre les citoyens et les autorités.

Objectifs. Cette révolution numérique crée un nombre florissant de nouveaux moyens pour impliquer la population dans la planification urbaine. Dans le cadre de cette thèse, je vais explorer l'un de ces moyens : l'utilisation des technologies 3D numériques participatives dans l'aménagement du territoire. Cette recherche a deux objectifs principaux : l'établissement de lignes directrices pour faciliter leur conception ainsi que leur implémentation, et l'évaluation des possibilités d'adoption de la 3D numériques dans les pratiques participatives actuelles.

Résultats. Les résultats présentés dans cette thèse élargissent la base de connaissances de toutes planifications urbaines impliquant la population avec un outil numérique en introduisant un vocabulaire commun et en cristallisant des concepts, qui soutiennent l'évaluation des supports participatifs actuels. Cette structure théorique étudie les approches participatives à travers différentes composantes telles que le projet urbain, le processus participatif, le médium interactif (ici, la 3D numérique), tout en mettant l'accent sur les participants affectés par le projet. Ces acteurs ont, en effet, un rôle crucial dans toutes approches participatives. Dans un premier temps, je propose un cadre d'évaluation de l'accès de la population à une session d'interaction, basé sur sept dimensions. Ce cadre vise à aider les autorités locales à adopter un médium en fonction des conditions d'accès du public cible à la session participative. Deuxièmement, je décris une étude en ligne examinant comment les participants manipulent un environnement géographique virtuel (un outil 3D) pour réaliser des tâches participatives. Cette étude suggère que les configurations participatives courantes ne permettent pas à la population de participer activement. Face à ces résultats, je présente donc des recommandations aidant la conception d'outils 3D numériques pour la participation citoyenne dans les projets urbains. Ces recommandations mentionnent la personnalisation de l'expérience utilisateur combinée à des affordances, ce qui permet de réduire le coût d'utilisation et d'améliorer l’expérience utilisateur. Le dernier volet de ma recherche explore la conception de prototypes successifs basés sur un globe virtuel, qui a été discuté avec des autorités locales et des experts urbains. La maturation progressive des prototypes conduit à l'introduction d'une approche simplifiée pour impliquer activement la population dans les processus de planification : le concept de participation de guérilla.

Conclusions. Cette thèse propose une analyse étendue de la participation citoyenne avec des outils numériques 3D en interrogeant les relations essentielles entre ce médium et les divers aspects des approches participatives. Cette recherche s'adresse aux praticiens, aux fonctionnaires, aux experts et aux chercheurs, en fournissant des outils cruciaux pour améliorer la conception de plateformes numériques 3D. Une amélioration ces outils pourrait promouvoir l’engagement de la population dans les projets urbains, conduisant à une participation plus inclusive, renforçant la légitimité de la prise de décision, et finalement conduisant à un développement meilleur et plus durable des villes.

Mots clés. planification urbaine participative et numérique, Civic Tech, sciences participatives, engagement citoyen, 3D, environnement géographique virtuel, Globe virtuel, SIG participatif

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“We are 21st-century citizens, doing our very, very best to interact with 19th century-designed institutions that are based on an information technology of the 15th century.”

Pia Mancini, co-founder of Democracy Earth and Open Collective. 2014

Chapter

1. Introduction

List of abbreviations for the chapter:

SDG: Sustainable Development Goals
UN: United Nations
SPA: Spatial Planning Acts
GIS: Geographic Information Systems
CGI: Computer-Generated Imagery
VGE: Virtual Geographic Environments
CIM: City Information Modeling
AR: Augmented Reality
VR: Virtual Reality
PPGIS: Public Participation Geographic Information Systems
ICT: Information Communication Technologies

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1.1. Motivation

In 2009, former President Barack Obama initiated a profound transformation of the governance conducted in the United States, which shifted towards more openness, transparency, and participation. He stated the following sentences during his speech preceding the signature of his first executive order:

> *"Our commitment to openness means more than simply informing the American people about how decisions are made. It means recognizing that government does not have all the answers, and that public officials need to draw on what citizens know."*
>
> **–** *(Obama, 2009)*

In these couple of sentences, he stresses that the government is not an omniscient institution and that there is an urgency in rethinking the role of the citizens, from information consumers to expertise providers. His mention of "*informing the American people*" refers to Arnstein's information rung from the citizen participation ladder (Arnstein, 1969). This influential continuum of participation introduces hierarchical levels of influence that the population can have over decision-making. The ladder levels are divided into three main categories: non-participation, tokenism, and citizen power (Figure 1.1). The information rung lies at the lower level of tokenism, which according to Arnstein, allows the population mere expression of power over decision-making. Therefore, when former President Barack Obama pinpoints the need to "*draw on what citizens know*", he acknowledges the intention of his administration to climb up the ladder.

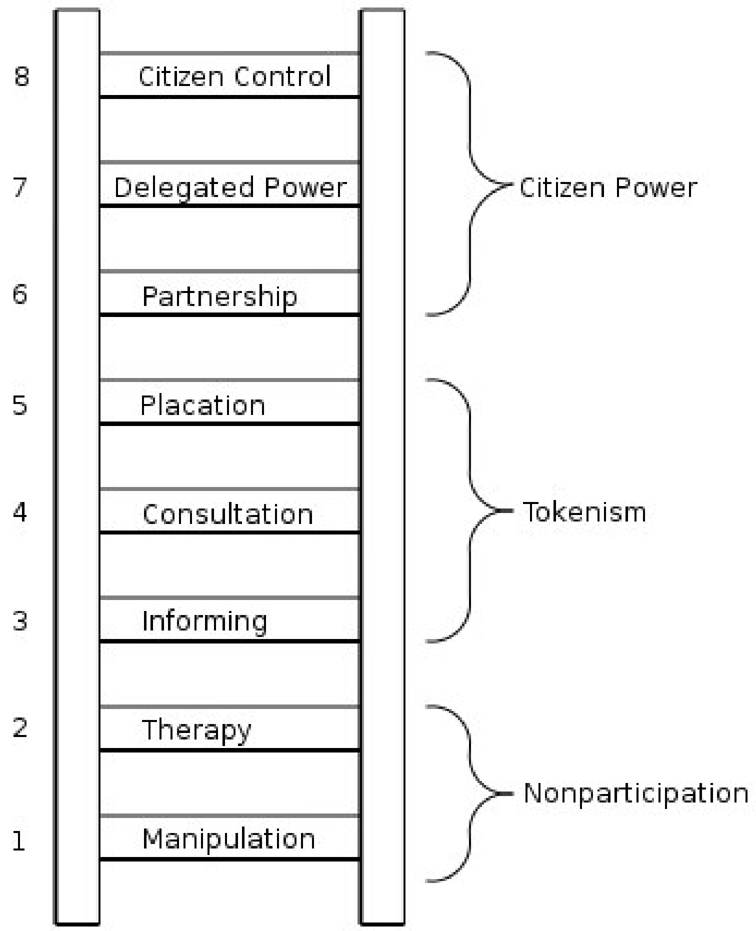


***Figure 1.1**. Arnstein's ladder introducing the degrees of citizen participation*

A few years before Obama's speech, L. Blondiaux and Y. Sintomer had already urged the institutions to administer their policymaking through a clear deliberative process (Blondiaux & Sintomer, 2002). According to them, the increase of the deliberation should: (1) create new information, i.e., initiate new knowledge structures that are developed through the wisdom of the crowds (Surowiecki, 2004); (2) support the development of stakeholders' cognitive structures based on the *constructivism* of the decision-making (Landry, 1995; Tversky & Kahneman, 1985), more commonly known as a learning process (Joerin et al., 2009); and (3) increase the legitimacy of the decision, notably by building social acceptance

(Wüstenhagen et al., 2007). However, several institutions are still hesitant in endorsing deliberative approaches with arguments such as the counterproductivity of engaging local communities that would have been involved nonetheless, the troublesome consequences of managing opposition, the menace of having activism groups monopolizing the debate, and the risk of driving the elected officials to be unaccountable for the decision (Blatrix, 2009).

The institutions are increasingly compelled to change their regard for public participation with an active social demand from the affected population and a gradual institutionalization of these approaches. The latter has been notably committed since 2015 by introducing the Sustainable Development Goals (SDGs), which result from more than 20 years of discussions about environmental protection and human well-being. With these SDGs, the United Nations (UN) emphasized the imperative of inclusivity and participation in decision-making in their Goal 16, which aims at promoting inclusive communities (Table 1.1). Moreover, in this Goal, the UN introduced indicator 16.7.2, namely "***proportion*** of the population who ***believe***", which means that "*doing*" participation is insufficient to reach satisfactory inclusivity in decision-making. The institutions should also design approaches that are trusted and acknowledged as legitimate by the population. Therefore, all efforts to lower the impact of participation in decision-making, i.e., restraining it to the lower rings of Arnstein's ladder, such as participatory washing, should not be considered admissible.

16 PEACE, JUSTICE AND STRONG INSTITUTIONS	***United Nations SDGs – Goal 16**. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels*
	***Target 16.7**: Ensure responsive, inclusive, participatory and representative decision-making at all levels*
	***Indicator 16.7.2**: Proportion of population who believe decision-making is inclusive and responsive, by sex, age, disability and population group*

***Table 1.1**. Goal 16 of the SDGs, which emphasizes the need for participation in decision-making (sdgs.un.org/goals)*

The same urgency of increased *citizen power* is also observable in urban decision-making and planning, which inscribe the participation in negotiations that are anchored to the spatial dimension. This requirement for public participation in urban issues is notably expressed by the description of SDGs Goal 11 about sustainable cities, which stresses the need for "direct participation [...] in urban planning" (Table 1.2). This impetus is also enforced by numerous Spatial Planning Acts (SPA), such as in Switzerland with the 2019 SPA (LAT, RO 700, art. 4); Quebec, Canada with the 2018 SPA (R.S.Q., c. A-19.1, art. 80.1); or France with the 2014 Lamy Act (LAMY, n°2014-173, art. 1) (Table 1.2). However, none of these official documents describe the exact conditions of the public's involvement or are supplemented by official guides (that detail the modalities of public engagement), which leaves the authorities alone in the design of the approach. This autonomy could lead to huge risks for the participatory approaches:

- The authorities do not always have the tools and the appropriate knowledge to design participatory approaches, which could lead to a poor negotiation arena (Innes & Booher, 2004) that could demotivate the participants to be involved.
- The authorities, as a shareholder, may alter the approaches to achieve their objectives (participatory washing) (Cooke & Kothari, 2001; Frediani & Boano, 2012).

	United Nations SDGs – Goal 11*.* *Make cities and human settlements inclusive, safe, resilient and sustainable*
11 SUSTAINABLE CITIES AND COMMUNITIES	***Target 11.3****: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries* ***Indicator 11.3.2:*** *Proportion of cities with a direct participation structure of civil society in urban planning and management that operate regularly and democratically*
Switzerland admin.ch/opc	***Art. 4 Provision of information and participation*** *2 - They shall ensure that the public are able to participate adequately in the planning process.*
Quebec, Canada legisquebec.gouv.qc.ca	***CHAPTER II.2*** *PUBLIC PARTICIPATION* *80.1. Every local municipality may adopt a public participation policy that contains measures complementary to those provided for in this Act and that promotes dissemination of information, and consultation and active participation of citizens in land use planning and development decision-making.*
France legifrance.gouv.fr	***TITRE Ier*** *: POLITIQUE DE LA VILLE (City policy)* *Article 1. Elle s'inscrit dans une démarche de coconstruction avec les habitants, les associations et les acteurs économiques, s'appuyant notamment sur la mise en place de conseils citoyens, selon des modalités définies dans les contrats de ville, et sur la coformation.* [non-official translation] *It is part of a process of co-construction with residents, associations, and economic actors, based in particular on the establishment of citizens' councils, according to the procedures defined in the city contracts, and on joint training.*

Table 1.2*. Goal 11 of the SDGs (sdgs.un.org/goals) and three examples of SPA enforcing citizen participation*

Urban projects often lead to strong opinions from the population due to transformations that concern people's living environment, which is emotionally connected to the affected dwellers (Sebastien, 2016). Intense disapproval could drive the population to confront the project proposal (urban struggles or NIMBYism[1]) (Devine-Wright, 2005). The requirement of involving the population aims at limiting the struggles and mobilizing the local knowledge of the urban dwellers (Akbar et al., 2020), the ultimate objective being improving the urban projects. However, the typical engagement approach (i.e., in-person for a few hours) leads to mobilizing the same small minority of participants (McLain et al., 2017). Thus, a large part of the population, i.e., the silent majority, is still absent from the participatory arena. Facing the complexity of motivating these citizens to get involved (Lotfian et al., 2020), the authorities must reinvent their engagement process.

[1] Not In My BackYard

Adopting digital technology is one solution to tackle these in-person participation issues and design better, more inclusive approaches. Since 2008, technologies have been increasingly used to reinvent public governance by improving the communication and exchanges between the population (or local communities) and the authorities. This transformation characterized by a technical pluralism is often titled Civic Tech (Schrock, 2019). These new digital tools aim at bringing governments and citizens closer to each other while making decision-making processes more direct, efficient, transparent, and fairer… A dramatic rise in the number of digital platforms was be observed since 2008 (Figure 1.2). This success demonstrates the urgency of digital transformation, which is developing at the same time as the transition to the Web 2.0, also named social Web due to its emphasis on social interactions (O'Reilly, 2007). The graph depicted in Figure 1.2, shows the dramatic increase in the number of Civic Tech projects from 2008, based on a dataset of more than 2000 digital projects (Civic Tech Field, 2019). A slight decrease, even a stagnation, can be observed for the years 2018 and 2019, which two causes can explain: (1) a better knowledge of the government's needs after a trial period that saw digital platforms flourishing; or (2) the adoption of a limited number of well-anchored platforms.

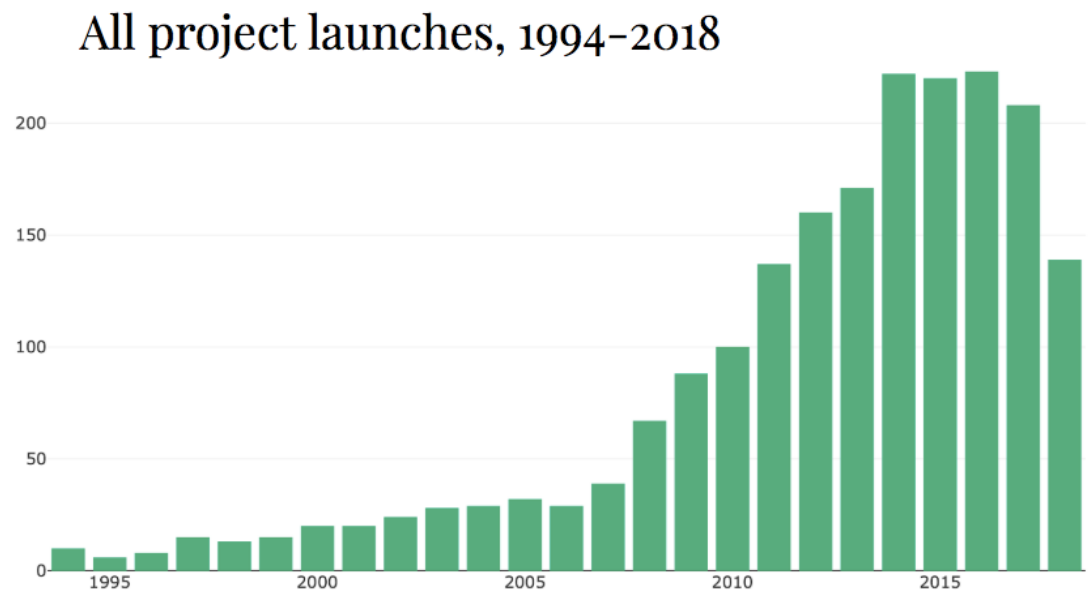


***Figure 1.2**. Growth of the Civic Tech projects launched worldwide between 1994 and 2018 (Civic Tech Field 2019)*

Civic Tech platforms such as DemocracyOs[2] from Argentina, Decidim[3] from Spain, or CitizenLab[4] from Belgium often allow citizens to share their preferences on various policies, propose projects in participatory budgeting, or give their opinions via surveys. However, these platforms often lack advanced mapping functionalities, which are critical for urban planning with their spatial (2D) dimension. The usefulness of digital 2D tools for urban participatory planning, notably with Geographic Information Systems (GIS), has been highlighted in the literature from the end of the 90s (Al-Kodmany, 1999) and the

[2] democracyos.org
[3] decidim.org
[4] citizenlab.co

beginning of the 00s (Rinner, 2001). These mapping tools, based at that time on asynchronous communication only, present a 2D visualization that is more frequently explored in a Western context. Urban dwellers have even acknowledged the value and accessibility of these mapping tools. They are eager to participate more often with collaborative digital platforms with a user-friendly interface and a low entry cost (no software installation nor background knowledge required) (Bugs et al., 2010). Moreover, based on a technology widely used by urban or geo-experts, digital maps can efficiently process geo-referenced content, which explains why numerous urban participatory projects have employed this technology (Czepkiewicz et al., 2018; Fechner & Kray, 2014; Haklay et al., 2018; Pánek, 2018a; Zhang, 2019).

In 2007, the world population living in urban areas reached 50% for the first time. In 2022, the figures are attaining 57%, corresponding to more than one billion individuals migrating to urban areas in only 15 years. According to the United Nations, in 2050, cities will accommodate an additional two billion individuals for a total of 68.4% (United Nations, Department of Economic and Social Affairs, Population Division, 2018). Authorities in charge of urban planning are facing new challenges in offering sustainable, affordable, sufficient, and livable housing. The need to densify the cities is highlighted in new SPA, notably in Switzerland with the enactment of the 2019 SPA. This densification should be explored vertically as much as horizontally, i.e., the municipalities have only a limited spatial extent to grow. However, increasing the height of the cities is often contested by urban dwellers (Ruming, 2018; Ruming et al., 2012). In this context, interactive 2D technologies, such as GIS, appear incapable of addressing these new challenges due to their incompatibility in depicting the vertical dimension (Figure 1.3). Therefore, the institutions should explore new participatory mediums that are more suitable for visualizing urban projects in all their dimensions, in addition to promoting efficient mechanisms of engagement.

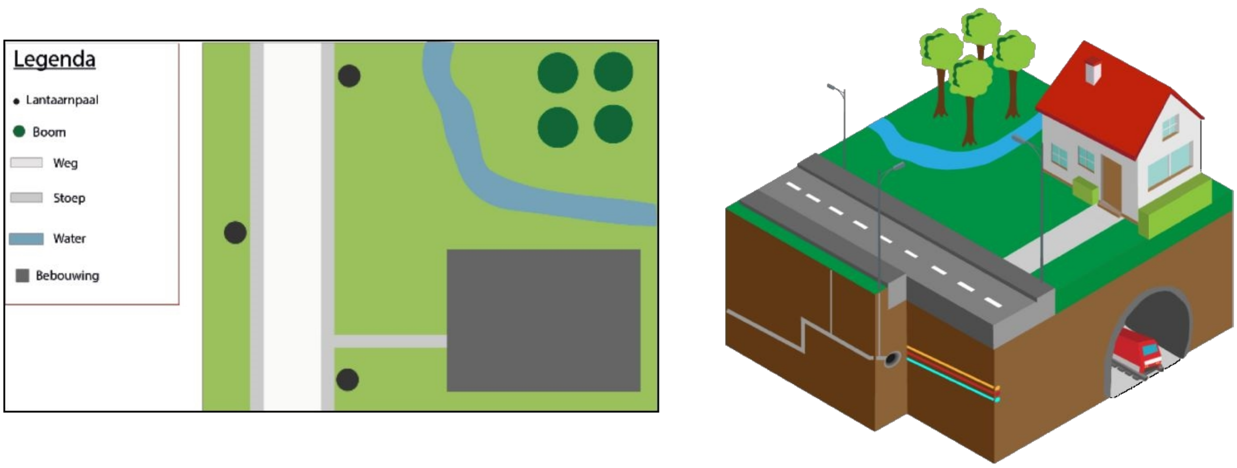


Figure 1.3. *Comparison of the same information depicted in 2D and 3D, which emphasizes the benefits of 3D visualization (Hermans-van Ree, 2018)*

The development of 3D technologies has been flourishing for a few decades, at first with the democratization of video game and movie industries with Computer-Generated Imagery (CGI). Their values for participatory planning have been acknowledged since 2001 (Al-Kodmany, 2001). The use of the 3rd dimension in urban participatory planning is supported by the implementation of Virtual Geographic Environments (VGE), which bridges virtual representations with real geographic spaces (Lin & Gong, 2001).

These VGE led to the development of several widely known tools such as the virtual globes and Google Earth[5], or the City Information Modeling (CIM), which supports a plethora of applications (Biljecki et al., 2015). The 3D mediums have many advantages for participatory approaches, including easier communication, more intuitive representation, a better understanding of volumes, and superior immersion (Çöltekin et al., 2016; Grêt-Regamey et al., 2014; Jacquinod & Bonaccorsi, 2019; Teyseyre & Campo, 2009). Unfortunately, their practices are still not widely adopted in urban participatory planning, notably due to the complexity of their implementation. Currently, these 3D technologies are rarely embraced by the industry, with only scarce examples, such as opencitiesplanner[6], and block-by-block[7]. The same dynamic can also be observed to a lesser extent in the scientific literature, where the mentioned projects are highly specific and short-lived (Alatalo et al., 2017; Hu et al., 2015; Virtanen et al., 2018).

1.2. Summary of the Main Objective

This research investigates the adoption of 3D technologies in urban participatory practices. The design of 3D participatory tools is complex and determined by several factors specific to participatory sessions. These factors will be explored through the lens of the transformations that the adoption of 3D technologies introduces in urban participatory practices and in the interaction between stakeholders. An enhanced design could encourage a broader engagement (i.e., increasing inclusivity), and create more opportunities to implement 3D participatory tools.

1.3. Research Scope: Use Context

The concept of public participation is fluid, i.e., varying, according to situational, contextual, and cultural factors. This research was conducted in Switzerland, where the population is already accustomed to participating and is often involved (popular voting, urban participatory planning). The definition of public participation adopted in this Ph.D. research comes from the Auditor General of British Columbia, Canada (Doyle, 2008):

> *"A deliberate **commitment** that government makes to its public and stakeholder groups **to listen** and **to be influenced within** expressed **limits**".*

This definition illustrates three crucial components of public participation (at least in the context of this Ph.D. research): (1) public participation is initiated by the government and involves the public or

[5] earth.google.com/web/
[6] eu.opencitiesplanner.bentley.com/site/
[7] blockbyblock.org/

stakeholders; (2) public participation is not only informing and consulting the population, but it is also, first and foremost, a mechanism that aims at shaping a project; and (3) public participation has rules defined in advance by the institutions, meaning that not every aspect of a project is under discussion. Furthermore, the institutions are owners of the decision, notably because they are accountable for any following steps of the urban project.

However, this definition of participatory planning does not describe its procedures of involvement, its purpose, or its scope. Planning approaches can, on the one hand, engage the population through aspects of the decision-making which influence the political decision. It is notably the case in Switzerland (where this research is conducted), where the population is involved in a public inquiry required by law. During this inquiry, the urban dwellers are free to submit their opposition to the urban project. All the filled opposition should be addressed by the promoters before the project can go any further in its completion. Still, in Switzerland, in some specific cases, the population can also vote on the urban project through a referendum. On the other hand, participatory approaches could also signify engaging the population through the planning process, where terms such as consulting, involving, or co-designing are often favored. This participation in planning engages urban dwellers with a debate that aims to build knowledge among the affected communities, generate and explore various alternatives, or co-create the urban project. This Ph.D. thesis will focus on this second form of participation, even if some of the proposed concepts, methods, and solutions are applicable in the first context.

The participatory practices under discussion in this research will be mostly digital and online. Civic Technologies (and the GovTech) are transforming democratic and participatory mechanisms by facilitating the dialogue between the institutions and the population by creating virtual interactive arenas. The development of these kinds of e-tools is currently flourishing, which can be overwhelming for institutions. In Switzerland, in 2019, a national survey, namely the Civic Tech barometer, was conducted with the institutions, which aimed to assess the adoption of digital tools in the current governance practices (Hausser et al., 2019). The results demonstrated that most institutions do not have a dedicated department for participatory approaches and are surprisingly unfamiliar with the concept of Civic Tech. Another study finding is urban planning appears to be a central challenge for present and future digital participatory approaches. Furthermore, the tools currently adopted by the institutions are often limited and simple in their mechanisms of involvement (online surveys, information websites, open data, social networks, participatory budgeting, online discussion, etc.). Therefore, this Ph.D. aspires to accelerate the development of Civic Tech and provide modern advanced e-tools to engage the population.

Additionally, this research explores digital 3D mediums in urban participatory e-planning. One of the central arguments for using 3D visualizations in participatory approaches is their ability to depict the height attribute of the portrayed elements straightforwardly. The focus of this Ph.D. research regards urban planning projects (more than landscape planning) because cities offer abundant opportunities to discuss the height characteristics of the projects. Numerous situations could be suitable to adopt 3D mediums, each leading to a specific practice such as the broadcast of video clips, the collection of dwellers' feedback, or the design of alternatives. This research mostly focuses on collecting citizens' feedback, concerns, or preferences through a 3D medium, preferably used online (but could still be applied to an in-person workshop). Therefore, participants are free from guidance in using the 3D medium, which adds complexity and entry cost to adopting these tools and applying their practices. Furthermore, this research will only consider 3D mediums that are broadcast on a screen. Augmented Reality (AR) and immersive Virtual Reality (VR) will be mentioned but not explored. Therefore, the 3rd dimension under discussion in this research cannot be considered as "real" 3D (seen through stereoscopy or an immersive setup) but as a 3D model projected on a screen, known as 2.5D or pseudo-3D.

1.4. Formulation of Research Objectives

The objectives and research questions raised in this research are articulated around the definition of participatory approaches (Figure 1.4 top). This Figure was first described in (Chassin, Cherqui, et al., 2021) (see also chapter 7). It depicts an overview of the mechanics that underlie the design and the execution of participatory approaches. Four key components are considered in these processes:

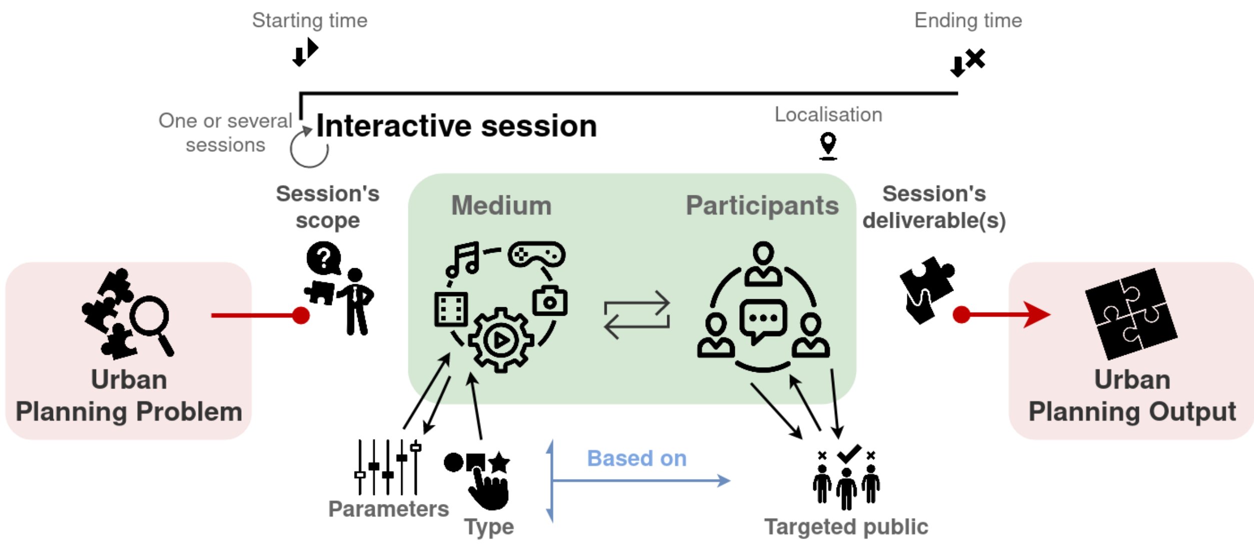
- ***The urban problem***. These approaches aim to address an urban problem defined and framed beforehand by the authorities. Urban problems have various purposes, such as creating a new house estate development containing several buildings, constructing a road, redesigning a park, revising the urban development strategy of a municipality, or implementing a playground for children. Facing these urban problems, a municipality can (or has to) commit to involving the population in certain (selected) aspects of the project. The participatory approach aims to deliver a *solution* to the overall project and its aspects under negotiation by involving the population through a unique or several subsequent moments of interaction.

- ***The interactive session(s)***. The moment(s) of interaction, or interactive arena(s), are organized in session(s) that are bound in time and located to a precise location (including online). The interactive session involves *participants* that contribute to the *solution* through a *medium*, i.e., an instrument that is used to enhance the communication, the interaction, and the exchanges between the actors taking part in the session. Figure 1.4 (bottom) depicts two examples of interactive sessions conducted in analog and digital settings. These sessions address a specific component of the *urban problem,* such as walkability, environmental challenges, noise regulation, or landscape values. These interactive sessions can take place at different phases of the project, leading to different objectives, settings, and modes of interaction.

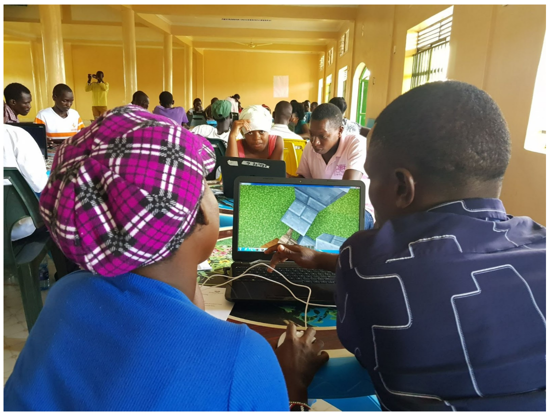
- ***The participants***. Individuals mobilized through an interactive session. The participants are directly or indirectly invited through processes of selection or self-selection. From the affected population by an urban project (often inhabitants living in the area), the authorities identify key stakeholders that are valuable to engage through various exercises. From this evaluation, the authorities select the targeted public they aspire to mobilize during a specific *interactive session*. The participants attending an interactive session can belong to this targeted public or not (depending on the selection process that can be stimulated by the selection of a medium, prior communication, etc.).

- ***The medium***. The medium, selected by the authorities, is defined by a type and unique parameters and represents the participatory object that stimulates the dialogue. A medium can have different shapes and is often related to the *interactive session*. For instance, it can be a city and oral explanations during an urban safari, a presentation and a session of Q&A[8] during public hearings, or written documents and post-its in a focus group. Figure 1.4 (bottom) shows the adoption of two different mediums: a 3D physical mock-up on the left and a digital 3D video game on the right.

[8] Questions and Answers



Gallieni - participatory session, Villeneuve-la-Garenne, France (©Bertrand Guigou)



Block-by-Block workshop Kalobeyei, Kenya (©ONU-Habitat). blockbyblock.org

Figure 1.4. *(top) Pictural description of participatory approaches and their components (urban problem, interactive session, participants, and medium) retrieved from (Chassin, Cherqui, et al., 2021). (bottom) Examples of interactive sessions adopting a 3D medium (non-digital and digital)*

The schema, Figure 1.4 (top), highlights the main focuses that will be investigated through this research, i.e., the ***participants***, the ***urban participatory practices*** (current and future), and the ***mediums*** (i.e., digital 3D visualizations). These aspects are often considered in the scientific literature in the form of questions: ***who?*** (related to the participants), ***when?*** (related to the participatory practices), and ***what?*** & ***how?*** (related to the mediums). However, these questions are frequently raised and discussed as aspects that should be considered in the design of interactive sessions or that explain the diversity and the challenges faced in participatory practices (Cooper et al., 2006; Rosener, 1978), but they are rarely answered.

For instance, Sieber stressed in a framework the significance of several components, which should be considered in the design of Public Participation Geographic Information Systems (PPGIS), i.e., another interactive medium that is widely adopted in urban participatory planning (Sieber, 2006). The components are related to (1) place and people, which encompass the context, the shareholders, and the public (i.e., *when* and *who*), (2) the technology and the data with the technological extent (or degree of freedom), the accessibility, the appropriability, and the representation (i.e., *what*); (3) the process that contains the implementation, the participation and communication, and the structures and process for the decision-making (i.e., *how*); and (4) outcomes and evaluation, which also focus on the goals. Similarly, Bryson et al. outlined twelve steps that should lead to designing better participatory approaches. These steps are divided into three aspects: (1) context and purpose, which is related to the use context (i.e., *when*); (2) resources and management that emphasize stakeholders (i.e., *who*), but also technical aspects, rules and structure to stimulate the participation (i.e., what and how); and (3) the evaluation of the process (Bryson et al., 2013). In the context of participatory 3D e-participation, Lovett et al. redefined these dimensions for landscape planning: (1) *when?*, which corresponds to the use context (or setting) of medium (purpose, audience, resources); (2) *what?*, namely the content depicted within the medium (features, realism, credibility); and (3) *how?* that regards the degree of freedom given to the users in terms of interactivity, display methods, or supplementary material (Lovett et al., 2015). However, the human dimension associated with the participants has been reduced to a subcategory of the use context (when).

The three aspects identified in Figure 1.4, namely the ***participants***, the ***urban participatory practices***, and **interactive mediums**, seem to accurately mirror the who, when, what, and how questions raised in the literature. Therefore in this research, I aspire to explore these aspects through the lens of 3D participatory e-planning. At first, I will focus on understanding and discussing the use context and the challenges related to the adoption of 3D visualizations in the current practices of urban participatory e-planning (when?). Then, I will assess the opportunities introduced by adopting an interactive medium (digital or non-digital) in a participatory session from the perspective of the population (who?). Later, I evaluate the relation between the participants and the settings of 3D mediums, including their portrayal and designed interactions (what?). Last, I will introduce modern prospects for using 3D visualizations in urban participatory e-planning practices (how?).

1.5. Publications and Links to the Research Objectives

This Ph.D. research is articulated around six scientific articles, published (or submitted) as the first author in conferences and journals both double-blind and peer reviewed. These publications constitute the different chapters that address the research objectives and questions, highlighted in the previous section. The publications are linked together and the most recent publications are developed based on the results introduced by previous publications (Table 1.3).

- Paper A: **Chassin, T.**, Ingensand, J., and Joerin, F. (**2022**) *Media Coverage of 3D Visual Tools Used in Urban Participatory Planning*, International Journal of E-Planning Research (IJEPR) [**in revision**]

- Paper B: **Chassin, T.**, Ingensand, J., Lotfian, M., Ertz, O., and Joerin, F. (**2019**) *Challenges in creating a 3D participatory platform for urban development*, Adv. Cartogr. GIScience Int. Cartogr. Assoc., 1, 3, doi: 10.5194/ica-adv-1-3-2019

- Paper C: **Chassin, T.**, Cherqui A., Ingensand J., and Joerin F. (**2021**). *Impact of Digital and Non-Digital Urban Participatory Approaches on Public Access Conditions: An Evaluation Framework*, *ISPRS International Journal of Geo-Information* 10, no. 8: 563. doi: 10.3390/ijgi10080563

- Paper D: **Chassin, T.**, Ingensand, J., Christophe, S., & Touya, G. (**2022**). Experiencing virtual geographic environment in urban 3D participatory e-planning: A user perspective. Landscape and Urban Planning, 224. doi: 10.1016/j.landurbplan.2022.104432

- Paper E: **Chassin, T.**, Ingensand, J., Touya, G., and Christophe, S. (**2021**) *How do users interact with Virtual Geographic Environments? Users' behavior evaluation in urban participatory planning*, Proc. Int. Cartogr. Assoc., 4, 19, doi: 10.5194/ica-proc-4-19-2021

- Paper F: **Chassin, T.**, Ingensand (**2022**) *E-Guerrilla 3D Participation: Concept, Implementation and Usability Study*, Front. Virtual Real. [**submitted**]

Main Objectives	***Based on the Results of***	***Discussed in***
Current Practices		*Paper A & B*
Participants	*Paper A & B*	*Paper C*
3D Mediums	*Paper A & C*	*Paper D & E*
Future Practices	*Paper A, B, C, D & E*	*Paper F*

Table 1.3. *Description of the relationships between the published papers*

Current Urban Participatory Practices – When? Integrating the third dimension in urban participatory planning with technologies, such as VGE, is transforming current practices. The adoption of interactive mediums is strongly related to the design of interactive sessions. The engagement of the urban dwellers is indeed conducted through participatory tasks that are based on a specific interactive medium. Hence, if the medium changes and no adjustments are made, the task will no longer be adapted to its medium, which can lead to obscuring the objectives of the session. Therefore, to employ digital 3D visualizations in participatory e-planning, specific interactive sessions and tasks should be implemented. Related to the current urban participatory practices, I aim to identify the typical settings related to the adoption of 3D visualizations in terms of use context and technical aspects (Paper A). Furthermore, based on the resulting observations, I aspire to highlight some of the most critical challenges in the design of 3D visualizations for urban participatory e-planning (Paper B). The discussions related to these two aspects (and publications) are discussed in chapters 5 and 6.

Participants – Who? Currently, no fit-all-situation medium exists to engage the broad population. This statement applies to digital and non-digital solutions. Each selected medium will indeed exclude a part of the population. This limitation is depicted in Figure 1.4, with the differences between the targeted public that is identified beforehand by the authorities and the participants that are mobilized for the interactive session. The gap between the actual participants and the population is crucial for selecting any medium or the design of any approach. The several acknowledged challenges regarding whom to invite, who is legitimate to participate, or what representativeness for participatory sessions are still laborious to address, and the authorities do not always have the tools or the knowledge to tackle them. Therefore, I aim for a tool to evaluate these elements through the perspective of access to an interactive session (Paper C). The development of guidelines and a framework to better select an interactive medium (digital or not) will be presented in chapter 7.

3D Mediums – What? One of the central elements of interactive sessions is the interaction between the participants and the medium (Figure 1.4). However, not every participant is equal in terms of abilities regarding 3D visualizations. Furthermore, the modification of the 3D portrayal such as the level of detail, or the representation may alter the judgment or experience of the participants. Nevertheless, interactive sessions should provide a neutral medium to deliver unbiased insights to address an urban problem (cf. Figure 1.4). If the 3D visualization is poorly perceived, participants may contribute with inputs that are not in line with the objectives of the interactive session. Thus, the available information and its portrayal are crucial to creating meaningful participation. Through the 3D mediums, I aim to investigate the relationship between the participants and the representation of the information depicted within a 3D medium (Paper D), in addition to the behavior developed by the participants (Paper E). These two elements will be developed in chapters 8 and 9.

Future Urban Participatory Practices – How? The adoption of 3D mediums in participatory approaches is flourishing. However, as seen in the *civic tech baromet*er (Hausser et al., 2019), the institutions tend to adopt basic settings that do not engage the full potential of digital tools and, by extension of, 3D technologies. Chapters 2 and 5 point out that most adoptions of 3D mediums are conducted in one-shot interactive sessions that are highly specific and not reproducible. In chapter 10, I aim to introduce new mechanisms which provide a user-friendly and simple interaction to any participants that would like to contribute to a project. The suggested method intends to explore an original approach to engage the population and enhance the quality of the information transmitted by the 3D visualization (Paper F), which could lead to more meaningful insights from the participants.

1.6. Thesis Outline

Chapter 1: Introduction. This chapter introduces the overall context of this Ph.D. project. The general motivations are introduced in plain language for any reader of any field. The motivations start from the requirement for public participation in governance to the urgency to innovate in this domain. Then, the use context of this project articulated around three themes is explained: the approach is initiated by the institutions, means involvement in planning, and takes place online. Last, the overall objectives and the research question addressed in this project are described.

Chapter 2: Theoretical Context. The theoretical context is presented in this chapter. The key elements of this project are summarized from the scientific literature. Therefore, this chapter can be addressed to any reader that would like to grasp general knowledge of 3D urban participatory e-planning. I discuss this state-of-the-art through three categories: (1) the urban participatory approaches from their opportunities to their limits, (2) the introduction of ICT[9]-based tools in participatory planning and the transformation of typical practices, and (3) the adoption of 3D technologies to enhance participatory planning.

[9] Information Communication Technologies

Chapter 3: Research Objectives. In this chapter, the four main research objectives are emphasized through the current practices, the participants, the medium, and future practices. These topics of interest are based on the research questions highlighted in chapter 1. A schematic description of these objectives is illustrated, and a link between the articles published during this Ph.D. research and the objectives is mentioned.

Chapter 4: Implemented Prototypes: Methods, Technologies, and Experiences. This chapter describes the approach that was used to conduct this research. The main mechanism is the development of prototypes (3D participatory e-platforms), which support the exploration of the notions, concepts, and hypotheses introduced during this research.

Chapter 5: Paper A - Media Coverage of 3D Visual Tools Used in Urban Participatory Planning. Currently, not much is known about using 3D visual tools (or 3D visualizations) in urban participatory planning. Some studies aim at collecting or presenting projects from an academic perspective. However, these approaches tend to describe particular projects that are not in line with the day-to-day concerns of practitioners. Therefore in this chapter, I propose a new lens that focuses on applied participatory practices. This lens is conducted through media coverage. A total of 120 media stories were collected with this method. The stories were then categorized and analyzed in light of two dimensions: context factors and technical parameters. This chapter extends the current knowledge around urban participatory planning projects adopting 3D visualizations, which is crucial to understand better practitioners' concerns in designing 3D participatory planning approaches.

Chapter 6: Paper B: Challenges in Creating a 3D Participatory Platform for Urban Development. Despite acknowledged benefits, 3D visualizations are still scarcely adopted in urban participatory planning. One of the main reasons for this lack of 3D initiative is the complex nature of these visualizations, which makes them difficult to design and implement. In this chapter, I dissect this complexity around three main categories: the use context, the interactive session, and the targeted public. These categories are associated with six challenges, which structure the discussion. Then, recommendations are suggested to facilitate the design of 3D visualizations for participatory planning approaches.

Chapter 7: Paper C: Impact of Digital and Non-Digital Urban Participatory Approaches on Public Access Conditions. Citizen involvement in urban decision-making has been thriving in the past years, notably because more and more Spatial Planning Acts integrate public participation as one of the pivotal pillars of sustainable urban development. However, the design of these participatory approaches is not straightforward, and the municipalities, left fully autonomous by the Spatial Planning Acts, do not always have the knowledge to design these approaches. A poor design can lead to several issues such as strong opposition toward the urban project, misrepresentation of the population in the participatory sessions, biases in decision-making, etc. This chapter, addressed to participatory approach practitioners (such as local authorities, professionals, urbanists, etc.), introduces a tool to support the selection of an appropriate participatory medium considering the public's access. A better medium selection could improve the citizens' involvement in urban projects, leading to informed decisions and ultimately increasing the quality of the urban development of a city.

Chapter 8: Paper D: Experiencing virtual geographic environment in urban 3D participatory e-planning: A user perspective. Adopting technology in participatory planning could enhance the citizens' involvement in decision-making. Virtual Geographic Environments, as a 3D spatial medium, are an attractive choice, notably because they facilitate understanding complex urban aspects by immersing non-experts in future projects. However, the complexity of creating these tools dissuades the local authorities from endorsing them. Indeed, an inappropriate design could lead to poor feedback, misunderstandings, or opposition from the population. This article assesses the real impact of different parameters that are being considered in the design of VGE. This chapter contributes to building knowledge about how the users experience and perceive 3D geo-visualizations. From this insight, I provided guidelines that could support practitioners (such as local authorities, urban experts, etc.) to enhance the design and use of VGE in their participatory approaches. Furthermore, I developed the chapter using an innovative method based on an online study, which could encourage peers to expand their research toolbox. Overall, the chapter aims to improve the citizens' involvement in urban projects by designing better participatory tools, which should lead to better decision-making and ultimately increase the quality of the urban development of a city.

Chapter 9: Paper E: How do users interact with Virtual Geographic Environments? Users' behavior evaluation in urban participatory planning. This chapter completes the analysis started in chapter 8 by exploring the interactive strategies developed by the participants during the achievement of their tasks. The investigation of these interactions can help identify specific behaviors related to hardship while manipulating a VGE. Recognizing these behaviors could enhance the VGE design by implementing specific assisting mechanisms that are dynamically introduced according to the participant's abilities, hence, promoting the inclusivity of VGE and digital participatory approaches.

Chapter 10: Paper F: E-Guerrilla Participation: Concept, Implementation and Usability Study. Interactive sessions in urban participatory planning tend to engage the participants in remote locations. These locations can be considered remote because participation does not occur within the area under transformation. This distance can hinder the contributions of the participants that could struggle to understand the concrete implication of the transformations under discussion. In this chapter, I suggest a glimpse of the urban participatory e-planning future by introducing and testing a new approach using a VGE. This approach, called e-guerrilla 3D participation, transfers the location of the participation directly enclosed within the area under transformation, i.e., *in situ.* The participants are immersed in the future project and can understand and assess the implication of the project straightforwardly. This modern approach has been tested and evaluated by participants (experts and non-experts), which acknowledged the opportunities enabled by this new approach.

Chapter 11: General Discussions. This chapter discusses the research goals introduced in chapter 1. Each discussion addresses a research goal (related to the four focuses: current practices, participants, mediums, and future practices) by using the findings developed through all described chapters. This chapter also offers an additional discussion, which puts the findings into perspective. Limitations of this Ph.D. research will also be mentioned.

Chapter 12: Conclusions and Perspectives. The last chapter of this research summarizes the main findings and suggests some outlooks that may be considered in the short-term or long-term.

Chapter

2. Theoretical Context

List of abbreviations for the chapter:

PPGIS: Public Participation Geographic Information Systems
ICT: Information Communication Technologies
SPA: Spatial Planning Acts
NIMBY: Not In My BackYard
GIS: Geographic Information Systems
VGI: Volunteered Geographic Information
VGE: Virtual Geographic Environments
IAP2: International Association for Public Participation
OECD: Organization for Economic Co-operation and Development
CIM: City Information Model
VR: Virtual Reality (VR)
AR: Augmented Reality
CGI: Computer-Generated Imagery
LIDAR: laser imaging detection and ranging
LOD: Level of Detail
BIM: Building Information Modeling
IVR: Immersive Virtual Reality
CAVE: Cave Automatic Virtual Environment
CAD: Computer-Aided Design

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My Ph.D. research primarily focuses on the exploration of 3D Public Participation Geographic Information Systems (PPGIS) in the context of urban planning. This field of study is transversal and mobilizes social dimensions with participatory sciences, sociology, and urban planning, combined with technical dimensions with 3D geo-visualization, human-computer interaction, perception, and web app development. Each of the chapter/published articles introduces its own theoretical context according to its objectives, research questions, and hypothesis. In this theoretical context, I focus my investigation on components related to citizens' participation and the adoption of Information Communication Technologies (ICT) in these processes, notably with 3D mediums. Three layers will investigate the theoretical context, each adding a level of complexity. First, non-digital engagement will be explored through the challenge of participation, from promises to shortcomings. Second, digital engagement will be discussed in light of the *opportunities* and *threats* that are introduced by Civic Technologies and their promotion of ICT-based participation. Third, the adoption of 3D technologies in participatory approaches will be considered and illustrated by examples.

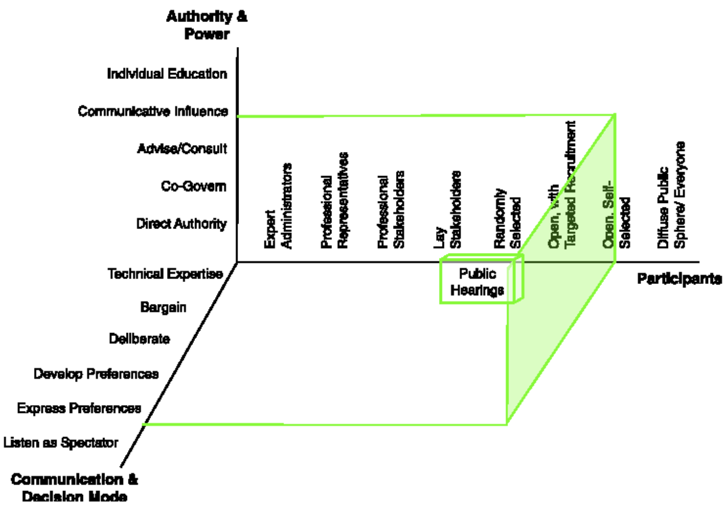
2.1. The Urban Participatory Planning Challenge

2.1.1. Objectives and Imperativeness

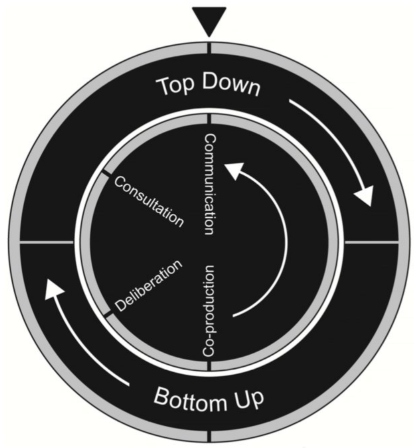
As already mentioned in the previous section, the practice of participatory approaches in urban planning, or at least the consideration of the dwellers in urban issues, is gradually becoming internationally enforced by several Spatial Planning Acts (SPA), which leads to the institutionalization of the participatory practices (Blatrix, 2009). Therefore, involving the population becomes more frequent (even standard) in the governance and planning of the cities. The involvement of the population in the transformation of cities acts as a binding agent between two conceptions of the city: (1) the distant politico-administrative perception of the institutions and (2) the living environment experienced by the dwellers (Lefebvre, 1970). The binding agent, i.e., the participation, creates an interactive arena where information can travel between these two conceptions, which manifest distinct knowledge.

The introduction in the literature of participatory continuums aims at describing and quantifying the level of public involvement in decision-making or planning, i.e., the strength of the binding agent between the two concepts of the city. Most of these continuums are depicted according to a hierarchy, where the desired end (often at the apex) offers the population the most freedom, control, or power (Baker et al., 2007). It is notably the case of the ladder of citizen participation (Arnstein, 1969), which describes nine rungs and three main categories (non-participation, tokenism, and citizen power) (Figure 1.1) or the spectrum of public participation (IAP2, 2014), which portrays five levels based on Arnstein's ladder (inform, consult, involve, collaborate, empower). Other representations of this continuum also exist in the form of cubes (Fung, 2006; Poplin et al., 2013), which define three axes (power, communication, participants), or wheels (Davidson, 1998; Reed et al., 2018), which divide a circle into separate categories: inform, consult, participate and empower (for Davidson), and top-down vs. bottom-up (for Reed). Figure 2.1 depicts a handful of examples of these participatory continuums.

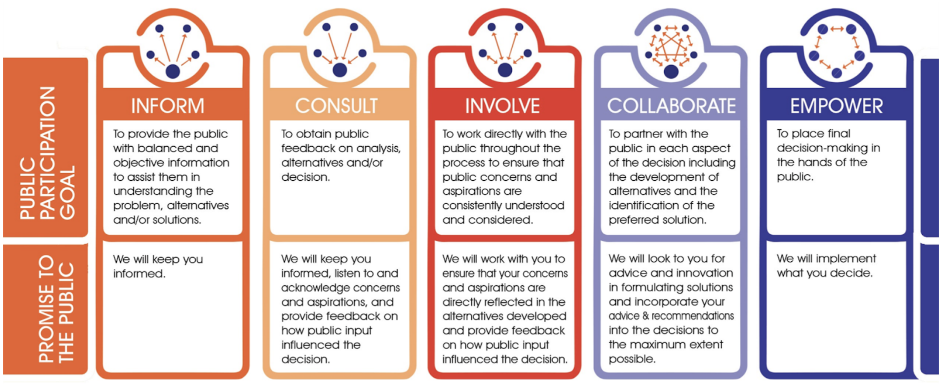
Most of the participatory continuums describe relationships of power on at least one of their axes, where on one side, the institutions have full control over the decision-making. On the other side, the citizens hold this power. Considering the role of participation as establishing a dialogue between the institutions and the citizens, the space of real collaboration (i.e., participation) can only be situated between these two sides. The goal of every participatory process should indeed be to empower both groups (Evans & Plows, 2007). Three spaces of empowerment (institutions end, citizens end, and interactive arena) were similarly described by M. Timney first in 1998, then in 2011, where she mentioned three citizen participation models: (1) an active model, which establishes a government controlled by the people with the institution playing the role of consultant, (2) a passive model that engages the citizens through information or consultation with the institutions in control, and (3) a hybrid model, later named collaborative network paradigm, where the governance is executed with the people, but conducted by the institutions (Timney, 2011). In this model, citizens and institutions always play a role in the participatory approaches, with the creation of channels that allow the transfer of knowledge (mostly through consultation) from one end to the other. However, the active and passive models still establish relations of power between the authorities and the population.



Fung's democracy cube (2006), retrieved from (Fung, 2006)



Reed et al.'s wheel of participation (2018), retrieved from (Reed et al., 2018)



IAP2's public participation spectrum, retrieved from (IAP2, 2014)

Figure 2.1. Examples of participatory continuum

The objectives of public participation are multiple and cannot be reduced to these dynamics of power where the citizens should be in control and have autonomy. Several purposes of the participatory approaches have been acknowledged in the literature (Bryson et al., 2013; Innes & Booher, 2004; Sexton, 2013). The objectives of participatory approaches can be categorized through five main dimensions:

- The first is to ***comply with the law***, where a legal requirement of participation is enacted by the new SPA.

- The second is to ***promote democratic principles*** supporting the ideas of social justice, fairness, inclusivity, equality, etc. Deliberative approaches (i.e., citizen involvement) support democratic values (Nabatchi, 2010). Good participatory approaches and the planning resulting from these processes are often described through precepts such as legitimacy (Cohen, 1989; Fung, 2015); social justice, fairness, and equality (Fung, 2015; Webler et al., 2001); or representativeness, trust, and transparency (Rowe & Frewer, 2000; Webler et al., 2001). These values also aim at limiting the power dynamics inherent in urban projects and participation.

- The third is to ***establish a dialogue*** (or interactive arena) between the institutions and the urban dwellers, which encourages understanding other stakeholders' points of view, sharing information, collecting opinions, or generating project alternatives. This dialogue is often defined as the establishment of a communication flow (one-way or two-way) between the institutions and the urban dwellers (Rowe & Frewer, 2000). This social dialogue constitutes a common ground between these two stakeholders that supports: (1) *one-way communication*: i.e., the transmission of information about the project that aims to understand the urban context and its specificities, and the constraints that the experts have to comply with; and (2) *two-way dialogue:* where the urban dwellers' opinions and concerns can be acknowledged by the institutions. This dialogue could enhance the social acceptance of the project (Wüstenhagen et al., 2007).

- The fourth is to ***improve the quality of the project*** by building "*on what the citizens know*"[10], i.e., their local expertise. Citizens indeed hold crucial local expertise linked to the livability of the place (Sintomer, 2008), a tacit knowledge hard to reach and grasp by external players such as institutions, urban experts, or practitioners. Urban dwellers also cultivate a specific spatial knowledge of the place that can be valuable to the planning process (Akbar et al., 2020). This knowledge cannot override the experts' broad vision and ability to plan cities. However, if used wisely, this knowledge could enhance the quality of the project, notably through the wisdom of the crowd (Surowiecki, 2004).

- The fifth is to ***empower citizens***. Engaging the population empowers the individuals and communities that are involved in the approach. This empowerment is developing through various dimensions. One of these dimensions is a learning mechanism, which concerns various aspects of the project (technical, contextual, economic), the affected neighborhood, and the other participants' perspectives, ideas, and points of view (Joerin et al., 2009). The participants also gain skills in participating, learning the rules, and customs of these processes (Irvin & Stansbury, 2004), in addition to building social networks within communities, i.e., promoting the creation of social capital (La Due Lake et al., 1998).

Public participation is and should be centered on the individual citizen and the mechanisms implemented to offer their appropriate and active engagement (Cooper et al., 2006). The degree of success of these participatory approaches is still difficult to assess because of different objectives, different interactive session settings, different citizens, and different evaluation methods (Abelson & Gauvin, 2006; Cooper et al., 2006; Rosener, 1978), which generate a versatility of contexts that are not reproducible nor comparable. However, if neutral and respectful of the participants, the interactive sessions can generate more engagement, more legitimacy of the approach and its outcome, and more social capital for the communities and individuals (Carpini et al., 2004), which is already a form of success. The practitioners and the participants have different views on how interactive sessions should be conducted and which should be the outcomes. In a Finnish context, participants value transparency, face-to-face exchange, expert availability, and efficiency (through a few sessions). In contrast, practitioners aim for cost-efficiency that would limit opposition and facilitate the acceptance of the project. Unfortunately, these two perspectives can be antagonistic, which could reduce the benefits of the participatory approaches.

[10] © Barack Obama

2.1.2. Today's Pale Picture

Despite the positive commitments of participatory approaches, their application is challenging and does not fulfill all their promises (Innes & Booher, 2004), and calls to change typical practices are voiced (Healey, 1998). The recently introduced spatial planning acts enforce citizen involvement as a mandatory planning process procedure. However, these SPA only mention the requirement of participation without specifying methods for their implementation (chapter 1.1). This gray area leaves space for institutions to design their own approaches. However, successful participation is complex due to numerous components to consider, such as resources (in terms of cost and time), scope, information sharing, and participants (Baker et al., 2007). Lacking adequate knowledge and resources to design these successful participatory approaches, it is laborious for the institutions to satisfy the imperativeness of the deliberation, as described by L. Blondiaux and Y. Sintomer (Blondiaux & Sintomer, 2002). Four interconnected dimensions seem to encompass most issues in designing participatory processes (Marzouki et al., 2022). The first dimension relates to urban governance; it involves issues in the application of democratic values, the management of power dynamics, and considering the participation's legal obligation. These challenges are directly analogous to the purpose of participatory approaches. The second dimension portrays the stakeholders; it is mostly articulated around their idiosyncrasies in terms of expectations, preferences, backgrounds, ideas, etc. The third dimension involves the application of public participation; it encompasses the organizational challenges of the interactive sessions, the role of the medium, and the evaluation of the performance of the participatory approach regarding the objectives, results, and impacts. The fourth and last dimension describes societal aspects; it includes issues of participatory access, notably according to financial conditions. These four dimensions appear to reflect the components identified for interactive sessions, namely the practices, the participants, and the medium (Figure 1.4).

Traditional (in-person) interactive sessions seem to lack crucial elements to fulfill the conditions of a successful participatory approach. G. Rowe and L. J. Frewer recorded, in 2005, several types of interactive sessions through the definition of their typology for public engagement, including citizens' panels, focus groups, public hearings, referendums, task forces, or workshops, among others (Rowe & Frewer, 2005). These involvement mechanisms require the participants to join the interactive session at a specific time and place, which often leads to mobilizing a few similar individuals (Kingston et al., 2000) that are portrayed as male, senior, educated, and financially stable (McLain et al., 2017). Interactive sessions are indeed regularly held on weekdays for several hours, which impedes daily workers, parents, or any individuals that have obligations from participating. In addition, the unique location of the sessions forces most of the participants to travel to the site where the participation takes place, which adds time to the already long sessions but also the costs that depend on the means of transportation. The resulting over-representation of certain socio-demographic characteristics leads to default democratic values that participation should promote, which has been extensively discussed in the literature through representativeness (Rowe & Frewer, 2000). The idea of representativeness implies reaching the full spectrum of affected stakeholders by an urban project. Identifying and mobilizing these stakeholders evenly (also called "the public") is challenging (Bryson, 2004; Reed et al., 2009) but crucial. Defects in terms of representativeness, which are introduced by creating "invited" space, could reduce the legitimacy of the resulting decision or increase power dynamics monopolized by elites having a strong social capital, hence limiting the voices of part of the population (Everatt et al., 2010).

In addition to the inherent representativeness issues of in-person interactive sessions, institutions face challenges in convincing the population to take part in participatory approaches. Several justifications have been raised in the scientific literature. Some are related to the perception that the population has on the authorities sponsoring the participatory approach; for instance, a lack of trust toward the political entities

(Henn & Foard, 2012) or approaches that legitimize the power entities in place, i.e., participatory washing (Cortner & Shannon, 1993). In these contexts, the citizens do not believe in the participatory approach. Other arguments involve flaws in the session design, such as the inadequacy of the sessions with skills, abilities, and knowledge of the participants (or the institutions) (Baker et al., 2007), or the adoption of participatory models based on specific Western countries' experiences that are not always in line with the participants' realities (Swapan, 2016; Zhang et al., 2019). These mismatches between the interactive session settings and the participants do not create a compliant interactive space, which dissuades citizens from getting engaged. Further considerations concern the rigidity of the procedures in which interactive sessions are designed, including poor flexibility that does not value enough the contribution of participatory approaches (Hasler et al., 2017), the expensive costs of participation (financial and temporal) (Irvin & Stansbury, 2004) that are not in line with the allocated budget, or the limited number of seats and resources regarding the size of the urban projects (Pickering & Minnery, 2012). As the precious set of arguments, the rigidity of the procedure developed through the institutionalization of participation does not offer favorable conditions for the participatory approaches.

Further understanding of skewed representativeness is rooted in the temporality of urban projects. The engagement of the population in the diagnosis and design phase of urban projects (Faliu, 2019; Wates, 2010) occurs well before the implementation of the project. This temporal gap can last several months or even years and be conducive to several structural changes in the project, resulting in a final tangible project having little in common with the one discussed with the participants. Therefore, the institutions are engaging the population on aspects of the project that can appear not tangible to the participants, which can lead to a lack of interest in the participatory approach. This dynamic is counterbalanced by participants (often having the same profile) that feel legitimate to speak up, for instance, the Not In My Backyard (NIMBY) phenomenon (Jobert, 1998).

The potential unlimited design possibilities of participatory approaches offer the opportunity to acclimate the high versatility of urban projects in terms of social, political-economical, contextual, and cultural aspects. However, the lack of a defined frame for their practices often impedes the institutions from creating successful interactive spaces with the populations. Acknowledged challenges are the consideration of the citizens' motivation and willingness to participate (Dai et al., 2022; Zwass, 2010), as previously mentioned, societal factors influencing the engagement (Kenyon et al., 2002), and the context of the issue that is addressed (Afzalan et al., 2017). These three challenges vary between projects, hence leading to poor reproducibility of successful participatory settings. Moreover, the characteristics that define a successful participatory approach are still unclear, and its effectiveness can only be measured if the objectives of the approach are well defined and understood by all the stakeholders (Rosener, 1978). According to M. Reed et al., four aspects (context, design, power, and scalar fit) should be considered to increase the beneficial impact of citizens' participation, which are promoting democratic values and respecting the specificities of the project (Reed et al., 2018). However, citizens' involvement still lacks initiatives outside the legal framework, notably because their implementation depends on a limited number of participatory optimistic, which struggle to justify the benefits of meaningful public involvement (participatory washing) to non-optimistic (Fung, 2015).

2.2. The Rise of Digital Participation Through Civic

Technologies

The use of digital technologies in governance, including urban participatory e-planning, is known under several names, such as e-Government (Linders, 2012; OECD, 2005; Yildiz, 2007), Government 2.0 (Eggers, 2007) or civic technologies (Civic Tech Field, 2019; Knight Foundation & Rita Allen Foundation, 2017). Adopting these technologies aims to improve the efficiency of the interactions between governments and urban dwellers, i.e., creating an enhanced interactive arena. Information Communication Technologies (ICT) are the foundation of these new methods of interaction and are supported either by the government (GovTech) or by civic companies (Civic Tech). Regarding the GovTech, Kenya and Taiwan have reached significant support of digital platforms such as eCitizen[11] (Kenya), which provides numerous digital services, and the g0v[12] (gov-zero) movement (Taiwan) that aims at improving governance mechanisms by allowing any citizens to "fork" the government. In this context, citizens can suggest various proposals (developed during Hackathons) to improve governance. The government then offers to try the proposal for an entire year and to evaluate the quality of the new "fork"; if governance mechanisms are enhanced, the institutions can adopt the "fork" version for a longer term. The term "fork" is borrowed from Git[13], an open source software that facilitates the decentralized control of files' versions throughout the evolution of a project; the concept of "fork" in this environment means to create a complete copy of an existing project and to take full control of this new project (or root).

In regard to the Civic Tech tools, according to an international expert panel introduced by People Powered[14], four Civic Tech platforms reach a score superior to 75/100 regarding aspects such as cost, needed expertise, functionality, accessibility, implementations, and transparency. These platforms are Decidim[15], Citizen Lab[16], Your Priorities[17], and Consul[18] (People Powered, 2022). As presented earlier in section 1.1., these platforms offer to the citizens and the institutions new, easier, efficient mechanisms of interaction, which improve on the one hand, the transmission of information for more transparency and more immediate feedback, and on the other hand, the collection of citizens' feedback or contributions, for instance through a vote, participatory budgeting, ideation functionality. The founders of such platforms aim to minimize the barriers to communication between urban dwellers and institutions by acting as a facilitation medium (Brabham & Guth, 2017). Lowering these barriers means: (1) creating customized tools driven by urban dwellers' needs and preferences, which enhance the engagement with the platform; and (2) teaching citizens the complexity of public decisions through these platforms. Implementing these digital participatory mechanisms is often seen as one of the foundations of the construction of the smart city (Pokore, 2020). However, adopting these platforms in governance is challenging and requires an iterative process and full cooperation between the public, the institutions, and the developers (Smith & Martín, 2021).

Urban (and landscape) planning has a strong spatial dimension that is complex to illustrate with words.

[11] https://www.ecitizen.go.ke/
[12] https://g0v.tw
[13] https://git-scm.com/
[14] https://fr.peoplepowered.org/platform-ratings
[15] https://decidim.org/
[16] https://www.citizenlab.co/
[17] https://www.yrpri.org/
[18] https://consulproject.org/en/

Therefore, the use of non-spatial digital technologies as described in the abovementioned examples (vote, ideation, budgeting) is not always adequate. Adopting any kind of visualization in these processes could facilitate understanding complex urban aspects and create a common language (Roque de Oliveira & Partidário, 2020). Geographic Information Systems (GIS), which embody the same language as the planning experts, have shown their efficiency since the late 1990s (Al-Kodmany, 1999; Peng, 2001; Rinner, 2001) and are now commonly used in participatory practices. These tools promote the representation in 2D of urban projects, the interaction with spatial data, and the contribution of geo-referenced comments and discussions. Since the late 1990s, digital technologies have continued to mature, notably with the development of social media and web 2.0 (O'Reilly, 2007), which also create new opportunities for urban participatory e-planning.

2.2.1. Digital Opportunities for Urban Participatory E-planning

The main benefits of the use of ICT-based participatory tools are the ability to mobilize a wider range of participants, adopt various technological mediums, simplify the information related to the project (to be understandable and easy to browse), and enhance the debate (Macintosh, 2004). Therefore, digital participation seems to be defined by its flexibility, which includes the integration of "big" information from different sources and the design of numerous e-tools of various shapes, thus promoting diverse channels or technological aspects. The versatility of e-tools promotes unique options, which citizens could choose to embrace according to their own beliefs, thus increasing the immediate number of participants. More contributors to the participatory sessions mean more material (i.e., data, perspectives) that ultimately leads to improving the debate arena. The multiplicity of digital tools is supported by several dimensions that should be considered during their design: level of participation continuum, the stage of the project (early vs. late temporality), stakeholders, technologies, rules defining the participation, length of the engagement, access to the interactive session (see chapter 7), communication, expected outcomes and their evaluation, and contextual factors affecting the participatory approach such as economic, social, or cultural aspects (Macintosh, 2004).

The opportunities of digital technologies have been studied extensively through the review of existing participatory e-platforms (Ertiö, 2015; Falco & Kleinhans, 2018; Gün et al., 2020). These reviewed platforms promote more or less complex participatory features such as polls, adding geo-referenced data points, ranking, or discussion forums, and were evaluated through different lenses: the design phase and objectives, the level of involvement, functionalities, the collected data, the information flow, and the pricing systems. These participatory tools are surfing on the development of the Internet, the market penetration of smartphones that allows a direct connection, and the transformation to a Web 2.0, which is more oriented toward social interactions (O'Reilly, 2007). T. Ertiö argues that mobile participation (mobilized through digital technologies) could allow individuals to participate at any location and time, thus improving engagement capacity. According to her, this kind of tool creates a new type of interaction that happens between citizens, in addition to the well documented one-way vs. two-way communication (Ertiö, 2015). Furthermore, ICT-based mobile tools, from the GovTech or Civic Tech, have the potential to capitalize on built-in sensors to create location-based interactions (Houghton et al., 2014). From their study, A. Gün et al. suggest that e-participation could encourage the approaches to be more agile, reflective, and data-driven (Gün et al., 2020). Other benefits of digital participation are the mobilization of new stakeholders, namely the youth, cultivating direct and efficient communication, reinforcing participatory approaches by enhancing inclusivity, collecting additional local knowledge, and creating mobilization (Afzalan & Muller, 2018). Digital technologies also play a role in co-production and co-creation (i.e., between the public and the institutions) by transforming traditional approaches, promoting new mechanisms of participation, automating some human-based tasks, promoting direct interaction, enhancing motivation, introducing new sharing capabilities, balancing decision-making powers (Lember, 2018; Lember et al., 2019).

Digital technologies and e-participation are transforming engagement processes, promoting citizen or government-centered approaches, and deepening the information flow between stakeholders (Desouza & Bhagwatwar, 2014). The citizens-centered (i.e., Civic Tech) and government-centered (i.e., GovTech) approaches involve the participants in different roles that are more or less active (Cardullo & Kitchin, 2019). Citizens' contributions, encouraged by ICT-based tools, i.e., supported by the Web 2.0 principles, are gradually articulating around the creation and the sharing of social content (Saad-Sulonen, 2012). Social network platforms already provide the tools to share, create, and comment, like digital social content, in addition to currently aggregating a large number of uploaded posts and gathering a massive active community. Therefore, by capitalizing on existing social platforms, the institutions can achieve effective, low-cost participation. Examples of the adoption of these social network platforms in urban participatory approaches can be found in the literature, such as with Facebook[19] and SecondLife[20] (Evans-Cowley & Hollander, 2010); or Facebook, Twitter[21], and Instagram[22] (Williamson & Ruming, 2020). By using these tools, institutions are able to mobilize a population that is often considered to be "hard to reach", notably through channels with a low entry cost (i.e., cheap, without setting up and already known to the population) (Evans-Cowley & Hollander, 2010; Twitchen & Adams, 2012), in other words, creating a new (virtual) arena for interaction (Sinclair et al., 2017). Besides these benefits, the population shows interest in employing these modern ICT-based tools, if easy-to-use, qualitative, secure, and efficient (Bugs et al., 2010; Yeh, 2017).

The embedding of digital technologies in governance seems to promote participatory approaches that are more in line with the objectives of public participation described in section 2.1.1. S. Dawes suggests studying ICT-driven governance through some objectives, including citizens-oriented services, cost and quality effectiveness, and the reform of the institutions based on transparency and trust (Dawes, 2008). These objectives emphasize democratic values and the creation of an effective interactive arena between the public and the institutions (both being part of participatory approaches principles). Therefore, the development of the GovTech and Civic Tech seems to be profoundly transforming traditional participatory approaches, while improving and satisfying the principles of the latter. The flexibility provided by ICT-based participatory tools can also support the development of new mechanisms of interaction, or interactive mediums.

2.2.2. The Specific Case of Participatory Mapping

[19] https://www.facebook.com/
[20] https://secondlife.com/
[21] https://twitter.com/
[22] https://www.instagram.com/

Kevin Lynch's influential book, *The Image of the City*, described urban spaces through five components: district, edge, landmark, node, and path (Lynch, 1960). According to him, these spatial components, recalled in mental maps, support the narration of urban spaces as seen by the dwellers. These city elements can be depicted on cartographic support through geometric features (point, line, polygon) specific to vector data. In the domain of GIS, vector data are used to portray real-world information. Therefore, map-based technology such as GIS appears to be a suitable tool to support urban representations and their spatial attributes. GIS has been acknowledged as useful for urban participatory planning for more than 20 years (Al-Kodmany, 1999; Talen, 1999), and several examples were developed in various contexts since (e.g., Czepkiewicz et al., 2018; Fechner & Kray, 2014; Haklay et al., 2018; Pánek, 2018a; Peng, 2001; Rinner, 2001; Zhang, 2019). These GIS-based e-tools, or geo-collaborative tools, introduce the creation of a remote shared arena between the public and the authorities, which promotes a synchronous and asynchronous collaboration, where the reasoning on urban issues is materialized through a cartographic medium (MacEachren, 2001).

E-participation through a cartographic medium is well documented in the literature. One of the most known methods is the Public Participation GIS (PPGIS), also called participatory mapping (Brown, 2015; Kingston, 2007; McCall & Dunn, 2012; Sieber, 2006), which aims at engaging participants through active contributions through their (local) knowledge. PPGIS methods are part of Volunteered Geographic Information (VGI) (Goodchild, 2007), which is broadly related to the creation of geographic user content. These methods can involve actively or passively the contributors of these tools. S. Zhang describes a typology related to geo-participation: *consultative* aims at collecting a large extent of contributions to facilitate decision-making, *transactional* focuses on government effectiveness, and *passive* indirectly exploits information already uploaded (Zhang, 2019). Participatory geo-tools are based on interactive cartographic representation, which initiates a dialogue between the participants and the cartographic object through interaction (Roth, 2013). Being promoted by the institution, the cartographic object collects active participants' contributions through participatory mapping, hence belonging to the *consultative* category. Most of the geo-participation tools also fit in this category, which is related to a consultation and collaboration level from the IAP2's[23] public participation spectrum (IAP2, 2014), as observed by (Babelon et al., 2021). Several geo-tools, also *consultative*, have been applied to participatory planning, such as geo-debate (Rinner, 2001), geo-questionnaire (Czepkiewicz et al., 2018; P. Jankowski et al., 2016), emotional mapping (Pánek, 2018a), geo-design or geosocial media (Haklay et al., 2018). Therefore, geo-participation can be defined as multi-purposes, multi-perspectives, and multi-users. Some studies aspired to regroup this multiplicity into one unique e-planning platform (Steiniger et al., 2016).

Map-based participatory tools have numerous benefits for planning. Hereafter, the key positive aspects will be described. First, participatory mapping tools have the same cartographical language as urban planning. Planning experts and urban dwellers can, therefore, employ the same medium to interact, and the resulting cartographic objects can straightforwardly translate the wisdom of the crowds and the public judgment (Brown, 2015). Also, the vector data provided by the participants can be easily processed and enhanced by visualizations and analyses already employed in the cartographic domain (Fagerholm et al., 2021; Müller, 2021). Second, the information collected with geo-tools appears to be more representative and accurate than with typical participatory methods (Brown & Eckold, 2020). Third, these tools are also flexible, which promotes better suitability to the project's needs through the designed tasks and the collected data, and more inclusivity with the implementation of multi-language versions (Kahila-Tani et al., 2019).

The digital medium appears to be favorable for designing effective, fruitful, and successful (in terms of

[23] international association for public participation

the number of participants) participatory approaches. Their portability to any type of device, including smartphones (Brovelli et al., 2016), could also encourage the engagement of new participants, hence reducing the number of individuals in the “silent majority”. However, the design of digital interactive sessions is complex and subject to notable challenges.

2.2.3. Current Shortcomings of the Digital Tools

A plethora of digital tools are developed each year for urban participatory e-planning (Civic Tech Field, 2019). Their multiplicity connected to one of the urban projects leads to numerous one-shot tools, majorly documented for a western context, that are difficult to recover or reuse in a different context. Hence, the institutions can be overwhelmed by the identification of an existing tool that fits their needs perfectly, and also challenged by its implementation. Non-western applications can be strongly affected, because of the significant gaps in the culture and context of the application (Kiwan et al., 2021; Zhang et al., 2019). Recently, C. Hafferty presented six practical and ethical considerations for e-planning tools based on a survey and semi-structured interviews: technical barriers, cost and data access, skills and confidence, equity and inclusion, trust and transparency, (geo-)privacy and security (Hafferty et al., 2022). These considerations outline practitioners' perspectives (and day-to-day issues) and echo challenges that have to be addressed in the design of participatory e-tools. These challenges, if not addressed correctly, could hinder the effectiveness and validity of participatory e-tools.

Some concerns are more frequently pointed out, such as the digital divide (Mossberger & Tolbert, 2021; Scheerder et al., 2017; van Dijk, 2017). The use of technology involves an entry cost that can limit access to the participatory approach. This entry cost is defined by a set of social/cultural conditions or technical abilities and can include barriers such as tool installation and setup, ownership of certain devices and subscriptions, or basic knowledge required to operate the tool. The participants have been acknowledged as decisive determinants for e-participation, with challenges such as a lack of engaged participants, committed non-targeted participants, and the uncertain quality of the contributions; all of these issues can result from poor availability and quality of the shared information and the perceived illegitimacy of the approach (Münster et al., 2017). The advertisement and communication related to the urban project and the participatory approach have been identified as crucial aspects of the success (in terms of engagement) of digital interactive sessions (Berg et al., 2020). These elements should be crucially considered, as they could lead to participation fatigue (OECD, 2004) or worse, such as a lack of trust and disbelief of participatory approaches. Non-western practitioners seem to experience similar issues in engaging citizens with the mentioned lack of trust, insufficient legitimacy of the participatory approaches, and poor interaction between the institutions and the citizens (Luciano et al., 2018).

Bold critics suggest that digital tools for participation or governance have failed in terms of legitimacy and inclusivity, where the voice of a few (selected) privileged individuals is conveyed by these mediums, with a majority that is still silent (Santini & Carvalho, 2019). These dynamics could be stimulated by the adoption of the more complex digital mediums, such as GIS, hence introducing significant ethical issues (Chambers, 2006; Sheppard & Cizek, 2009). Furthermore, digital technologies do not appear to affect established patterns of involvement, where individuals or communities with higher social capital will still be more likely to be engaged (in digital or non-digital settings) (Carvajal Bermúdez & König, 2022). Moreover, digital tools alone seem insufficient to promote meaningful participation, and they need to be fortified by in-person sessions (Evans-Cowley & Hollander, 2010). The interactive arena between the authorities and the public is indeed entirely migrated online, which affects and limits the stakeholders' interactions that may need face-to-face confrontation in specific cases, such as conflict resolution or the conduction of complex participatory tasks. And, the emotional sentiments inherent to interactive sessions (Harvey, 2009), seem unrealistically collected by a digital medium. The definition of a successful or effective participatory approach is not clarified by the introduction of digital technology, which adds fluctuation in the design process of interactive sessions, which are already complex to implement. N. Afzalan et al. categorized this volatility into five dimensions: (1) the capacity of the institutions to implement and conduct the participatory approach; (2) the abilities of the population to adopt and use digital tools; (3) the objectives of the session, which should be clear, achievable (by a set of rules) and suitable to the context of the project; (4) compliance with the legislation; and (5) capacity of the digital tool to create a shared arena (Afzalan et al., 2017).

Furthermore, digital geo-participation adds a new layer of complexity and challenges. Looking in depth around three challenges of public participation, namely effective implementation, broad engagement, and qualitative contributions, it is unclear if PPGIS offers the best interactive medium. Measuring the (positive or negative) effect of PPGIS in planning practices is still laborious, and no clear evidence has been demonstrated for their capacity building, their community empowering, their outcomes applicability in governance, or their impact on the behavior of participants (Brown & Kyttä, 2018). Moreover, PPGIS has certain well-known benefits, but also several limits, which are extensively discussed in several studies (Kahila-Tani et al., 2019; Sieber et al., 2016), and include organizational issues (lack of resources in terms of knowledge, skills, and budgets), lack of inclusivity (non-representativeness, bias, and inequities), the reduction of the distinction between experts and laypersons, noise in the contributions (personified by *trolls* and stimulated by anonymity), and the reduced impact of digital insights in decision-making (probably due to the aggregation of the contributions which limit their granularity). Digital and geo-participation produce a significant amount of (“big”) data, which needs to be managed and stored, hence having a cost for the institutions (Dawes, 2008; Falco & Kleinhans, 2018). The implementation of GovTech and Civic Tech solutions confers the production of data to the participants, which leads to issues about legal aspects of the ownership of the contributions gathered during the approach (Kingston et al., 2000), the quality and security of the contributions (Balázs et al., 2021; Marzouki et al., 2019; Møller & Olafsson, 2018), and the creation of mechanisms to fusion the produced information (participatory data can be from a two-way interaction with various formats, sources, or technologies).

To simplify the design, implementation and management of digital participatory tools, the institutions can adopt platforms that are not primarily designed for planning, such as social media. This alternative could be a useful proxy, with a large pool of potential participants, and social capabilities that could replicate a handful of participatory activities. However, social platforms appear to deliver inputs that are not valuable for planning processes (Mattila & Nummi, 2022). Also, due to initial non-participatory purposes and the number of users, the online debate is challenging to facilitate (Williamson & Ruming, 2020). Overall, the practice of e-tools, promoted by the GovTech and the Civic Tech, seems to be conducted to “do participation”, without a clarification of its purpose, its integration in the planning outcome, or the role of the information collected (Hasler et al., 2017). The current implementations appear inequivalent, and far from reaching participatory objectives, but their plurality leaves space to innovate and create improved participatory sessions.

2.3. Virtual Geographic Environment, and 3D

Participation

Citizen participation and digital participation are challenging to implement; however, they seem to be necessary to enhance the understanding and legitimacy of gradually more complex urban projects. Citizen participation has been discussed for more than 50 years (Arnstein, 1969), its institutionalization for at least 30 years (Blatrix, 2009), followed by the development of e-governance capitalizing on digital technologies and the development of the Web 2.0 (O'Reilly, 2007). The use of digital tools, enhanced by GIS technologies, now appears to be anchored in participatory practices, after more than 20 years of experiments and applied projects in various contexts. Therefore, participatory approaches seem to evolve slowly. However, technologies have encountered evolution and several breakthroughs during this period, supported by constant improvement in storage, bandwidth, and computational power capacities (Hilbert & López, 2011). These technological leaps helped to develop numerous new advances such as blockchain, machine learning, and cloud computing. The 3D technologies are also included in these advancements with sub-domains such as virtual geographic environments (VGE), city information model (CIM), (immersive) virtual reality (VR), and augmented reality (AR). These technologies are now well-known to the broad population that has become increasingly proficient with the 3D medium, notably due to the market penetration of some champions such as the movie or video game industry based on Computer-Generated Imagery (CGI) or Google Earth. Moreover, with the technological enhancements in remote sensing (photogrammetry, or laser imaging detection and ranging [LIDAR]) and machine learning, real objects can now be measured, collected, and digitally recreated faster and more accurately. Hence, new 3D (city) models are created and extensively used in various domains such as transportation, energy, construction, simulation, or planning (Biljecki et al., 2015).

The adoption of 3D visualizations and models could significantly enhance urban participatory e-planning. One of the main benefits of using 3D is the straightforward depiction of heights and volumes, which is becoming fundamental in planning with the (vertical) densification of the cities. In this context, 3D visualizations could assist urban dwellers in better understanding the implication of such vertical development in their neighborhoods. However, few experimentations are conducted in applied projects or in the scientific literature, which leads to insufficient knowledge of how these 3D visualizations could practically enhance and transform current practices.

2.3.1. A 3D Medium for Visualization and Collaboration

As a visualization tool, 3D mediums improve communication by reducing the language barriers and establishing a shared understanding of the reality that is portrayed (Metze, 2020; Roque de Oliveira & Partidário, 2020). This ability draws on the role of visualization as a boundary object, which depicts information in a shape that can be apprehended through distinct cognitive structures (Star & Griesemer, 1989), thus facilitating collaboration and interaction. In other words, boundary objects, such as 3D mediums, are shared by the different participants having distinct perspectives, and thus can be used as a common body to facilitate negotiation between different stakeholders; as already identified for the GIS medium (Harvey, 1997; MacEachren, 2001). Furthermore, depicting complex information on a 3D medium seems to aid the (spatial) understanding of the elements that are represented (Al-Douri, 2017; Bouzguenda et al., 2021; Hayek, 2011), notably by their intuitive, straightforward representation of landscapes (natural or urban) (Schroth et al., 2011), which are easily understandable by non-experts (Al-Kodmany, 2001). Therefore, 3D mediums are effective communication channels that could enhance collaboration.

Another aspect of the 3D mediums is their ability to connect the participants (or users) to the place that they are portraying. The realistic representations conveyed by 3D visualizations connect the consumer of the visuals to the location that is virtually depicted, creating a sense of place, which delivers a meaningful connection with the medium through emotion and feeling (Naz et al., 2017; Newell & Canessa, 2015). A sense of presence can also be experienced through (immersive) 3D mediums, even if the quality of these two experiences varies according to different parameters, including prior knowledge of the place (Jaalama et al., 2021). A place is not only a geographical space but also a space of interaction between the built/natural environment and the human-given meaning (i.e., creating an ambiance), which is perceived differently according to individuals (Brown et al., 2020; Piga et al., 2016). Therefore, the sense of presence (i.e., linked to the technology) and the sense of place (i.e., linked to the real environment) are crucial for establishing meaningful participation because these two concepts reconnect consumers of a virtual 3D visualization to the real place, not only in terms of location but also through a real experience (i.e., feeling) of the place. Hence, participants' contributions could be more accurate to their true experiences. This connection to the place under transformation (i.e., the urban project) could tackle one of the challenges of public participation, which locates the engagement of the participants outside the affected place by the project. Collaboration about a place could even be extended to non-local participants through these 3D visual tools (Onitsuka et al., 2018).

Moreover, the design of virtual 3D models involves the capacity to add a new layer of information that could simply be integrated into the portrayed real environment. Through 3D, this additional information could be explored, analyzed, or described (Teyseyre & Campo, 2009). The depiction of future elements, such as buildings or simulations, on the right virtual scale, can help to engage the population with another language than the one provided by experts and professionals (Sheppard & Cizek, 2009). However, the representation of future development is not straightforward nor easy; numerous aspects have to be considered to avoid bias or misunderstanding (Judge & Harrie, 2020; Sheppard & Cizek, 2009). For instance, citizens can perceive a future project that considerably differs from the built project (Downes & Lange, 2015), and some project elements within the VGE can remain undiscovered due to occlusions (Elmqvist & Tsigas, 2008). However, the additional layer of information can provide complementary data such as photo-montages or text explanations further describing the project, and elements that could help the participants to navigate through the virtual environment. These elements can cultivate an eagerness to participate, facilitate interaction with the 3D model, and create narratives of the project through storytelling, for instance (Thöny et al., 2018). The creation of storytelling could also assist the participants/users in navigating the cluttered information and completing their participatory task by providing visual cues or filtering irrelevant information, hence limiting the risk of cognitive overload (Mayer & Moreno, 2003).

The 3D medium (as an interactive virtual arena) also promotes interactions between users of the visualization, the portrayed data, and the institutions that coordinate the participatory approach. The nature of 3D interactions is based on 2D GIS technology, which is implemented in 3D through the concept of VGE (Lin et al., 2013; Lin & Gong, 2001). VGE interconnects four components: data, model and simulation, interaction, and collaboration. The interaction within the 3D environment, i.e., exploration, allows users to choose their own vantage points to observe specific elements such as the future urban project (Herbert & Chen, 2015). The freedom of selecting different points of view could limit (intentionally or unintentionally) perspective biases (Downes & Lange, 2015), for instance, an oblique view that shows a high building as less impactful on the landscape than in reality. The metaphors implemented to manipulate VGE should be carefully designed in order to facilitate the exploration of the environment (access, legibility, edition), which should lead to a better presence in the virtual environment (Stanney et al., 1998).

Despite numerous alternative techniques, the complexity (i.e., freedom of interaction) of the implemented metaphors should consider the technical abilities of the users, and be flexible, if possible, to avoid any frustration (Jankowski & Hachet, 2013).

However, adopting 3D in urban participatory planning also increases the complexity of the medium, which leads to the exclusion of a part of the population. Numerous ethical aspects should be considered in their practice to meet the requirement of inclusive use, notably because not all stakeholders are equal regarding technology and visualization (Çöltekin et al., 2016; Schroth et al., 2011; Sheppard & Cizek, 2009). These differences could lead to misunderstandings that may be dramatic for the outcome of the urban project. The broadcast of a 3D visualization of the future project tends to crystallize the image of the portrayed project in the population's imaginary, which could be an issue for the participatory approach, for instance, if the participants do not conceive the reach of their contributions in a project that is “already decided”. Therefore, all 3D visualizations should be designed carefully, which could lead the institutions to limit their application, facing the high level of understanding and expertise needed to implement 3D tools, even on 3D tools which seem to be familiar to experts and the broad population, such as Google Earth (Smith et al., 2020).

2.3.2. The 3D Medium

The adoption of VGE in urban participatory e-planning can enhance the practices relying on the multiple dimensions of this 3D medium. The flexibility offered by VGE supports the diversity of contextual factors altering participatory approaches. The multiplicity of geo-visualization (thus the one of VGE) has been described through four exploration capacities in use, style, interaction, and perspective (Christophe, 2020). These capacities promote to the VGE a significant versatility to fit the contexts, the information and the participants by implementing interactive rules, various portrayals, visualization and manipulation mechanisms, assisting tools, and relative freedom. However, as previously mentioned, for digital tools, increased flexibility often leads to complex implementation. In their study, A. Çöltekin et al. define three main categories that encompass the challenges in the use of geo-visualizations: data and technology, representation, and human factors (Çöltekin et al., 2017). These categories mirror the dimensions identified by R. Sieber in her framework regarding the use of PPGIS: place and people, technology and data, the approach, and the outcome and their evaluation (Sieber, 2006). In the PPGIS framework, the question of representation is included in the dimension of technology. Also, the PPGIS framework adds two dimensions related to the participatory approach in which the PPGIS medium is used. In the previous sections, I have addressed the dimensions related to the approach; therefore, in the next paragraphs, the geo-visualization-oriented categories will be discussed through the lens of 3D.

Data and technologies. 3D medium supports the fusion of different types of data (real, future, or analytical) in the same virtual space. The aggregation of various sources adds value to the use of VGE because it can combine information from the actual urban space under discussion, the transformational aspects added by the project, the contributions from the participants (that have different perspectives), and real-time indicators related to the interactive session. However, the aggregation of “big” data in the same virtual space tends to increase the complexity of the support, i.e., visualization, in terms of obscuring the legibility or increasing the requirement of data management, storage, evaluation methods, ethics, and security (Çöltekin et al., 2020; Johansson et al., 2016; Marzouki et al., 2019; Müller, 2021). Moreover, these complex, voluminous 3D models need to be shared between the stakeholders.

The development of modern web technologies such as WebGPU[24], HTML5[25], three.js[26], or game engines working within a browser (e.g., Unity[27]), is facilitating the creation of 3D applications. Web technologies have been acknowledged as optimal support to host interactive sessions using VGE, where 3D visualizations can be quickly shared with a broad population without installation requirements (Virtanen et al., 2018), thus lowering the entry cost of the session. However, the use of a browser based 3D model introduced a few challenges. First, a good understanding of these applications is required to select the best technological stack, and architecture of the tools, but also to be able to implement the web applications (Dambruch & Krämer, 2014; Krämer & Gutbell, 2015). Second, the volume of the shared virtual scenes can be voluminous, hence challenging available bandwidth and device performances (Alatalo et al., 2017; Dambruch & Krämer, 2014; Krämer & Gutbell, 2015); therefore, significant download waiting time or lags can be experienced during participatory tasks, which hinder the engagement of the participants.

Other new technologies are also increasingly adopted in urban participatory planning, such as Immersive Virtual Reality (IVR), Cave Automatic Virtual Environment (CAVE), or Augmented Reality (AR) (Chowdhury & Schnabel, 2020; Heldal, 2007; Salter et al., 2009; van Leeuwen et al., 2018). These technologies appear to enhance the dialogue within the interactive session, the feeling of immersion, the engagement, and the understanding of the urban projects. These capacities are developed through the integration of digital elements in reality or *vice versa*, as described in the *reality-virtuality continuum* (Milgram et al., 1995) (Figure 2.2). However, participants and experts need help to use these tools due to their complexity, and the high cognitive load conveyed by these technologies (Heldal, 2007; Salter et al., 2009). The use of head-mounted displays or immersive technologies are reducing the surroundings of the participants to a unique screen and a virtual space. Furthermore, their uses are limited to workshops, which are often located far from the place under transformation. Therefore, immersive technologies seem to limit the connection that the participants have with the space, which is confined to a virtual environment. Regarding AR, due to the difference in lighting when used indoors (since it is brighter outside), the device needs some calibration to be perfectly functional (Devaux et al., 2018). Also, several challenges still remain (van Krevelen & Poelman, 2010), and questions on the depth and geo-localization of virtual elements in the real environment are still not addressed.

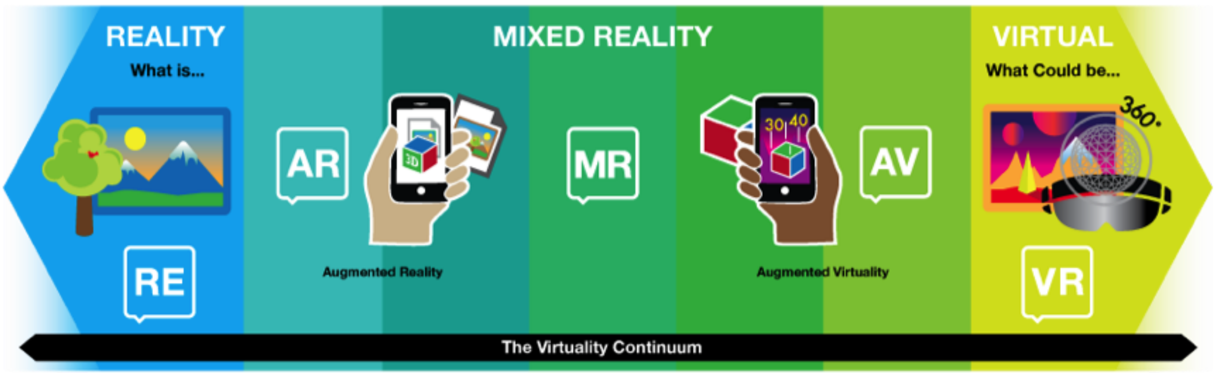


Figure 2.2. *Reality-virtuality continuum, which was first described by (Milgram et al., 1995)*

[24] https://www.w3.org/TR/webgpu/
[25] https://whatwg.org/
[26] https://threejs.org/
[27] https://unity.com/

Representations. 3D visualizations often convey the first image of an urban future project, long before its realization. Thus, these visualizations are crucial to building a common imagination around the project. The project should be mindfully designed and represented within the 3D medium by the institutions/creators to avoid any uncomfortable position with the population. With the lengthy time frame of urban projects (from several years to sometimes decades), the selection of the 3D medium's level of abstraction is challenging. The authorities can adopt either an abstract representation which could help the creative or ideation process, or a realistic representation that is more intuitive, comprehensive, and conveys more emotion (Hayek, 2011). The type of representation can affect the immersiveness of the participant within the 3D environment (Appleton & Lovett, 2003; Çöltekin et al., 2016), i.e., the connection between the participant and the medium. The degree of abstraction should be mindfully selected to be in line with the temporal phase of the urban project (Kibria et al., 2009), and the task to perform (Boér et al., 2013; Hayek, 2011).

Realism appears to be effective for communication purposes; however, realistic representations are often complex, with numerous elements to portray, leading to a high cognitive load and fatigue experienced by viewers (Voinov et al., 2018). A gap exists between the preference of the population skewed toward more realism and their actual performance with a detailed representation of the space (Smallman & John, 2005; Zanola et al., 2009). Creating a realistic VGE is also time-consuming and, if highly detailed, can be computationally expensive, i.e., more polygons are displayed in the 3D model. The complexity of the 3D model is described through the Level of Detail or LOD (Biljecki et al., 2014, 2016), which is defined according to the complexity of 3D elements (city model or building model)[28]. For city models, the LOD describes the presence of vegetation, leaves, street furniture, indoor furniture, chimineas, or awnings (Figure 2.3). However, very detailed models are not essential to provide an accurate orientation within a VGE or provide an accurate understanding of the place (Appleton & Lovett, 2003); an increased LOD can even hinder the orientation (addition of cluttering information) (Gardony et al., 2022), and realism is not necessary for graphic communication (Tversky, 2005). The portrayal of structural elements (through blocks of buildings and a basemap) and the ability to observe a virtual scene from a high bird-eye-view seem to be significant factors enhancing the orientation of the users/participants in a VGE (Handali et al., 2021; Zheng & Hsu, 2021). The ability of the participants to orient themselves within a virtual environment is crucial for the participatory session because through orientation; participants can locate themselves within the model, link the virtual to the real space and explore the environment.

Abstract representations appear to be very efficient for specific participatory tasks such as collecting information to identify problems, opinions, or ideas (Hayek, 2011). These representations limit the number of information conveyed within the VGE by filtering, thus reducing the cognitive load and focusing the attention on the place under negotiation (Judge & Harrie, 2020; Skulmowski & Rey, 2020). A low level of realism can display a reality, which can be suitable for specific tasks (Lange, 2001), without a need to detail the 3D environment further. However, due to their abstraction, these representations often add or highlight data, portrayed schematically, which are explained through an extensive legend box that leads the users/participants to split their attention (Hayek, 2011). Therefore, abstract and realistic representations of the space appear to have advantages and disadvantages, which depend on the tasks to be accomplished. To balance the impact of the individual representations, mixed representations are also explored and seem to have a strong potential (Brasebin et al., 2016; Lokka & Çöltekin, 2019).

[28] The LOD for city and building models should not be confused with the Level of Development (also abbreviated LOD) that is employed in the Building Information Modeling (BIM). The level of development introduce six levels: 100 (Concept), 200 (Schematic), 300 (Precise), 350 (Precise with Connections), 400 (Fabrication), 500 (As-built). It describes the amount of detail present in the model following its development phases (BIMForum, 2013).

In addition to the representation of the elements portrayed within the virtual geographic environment, 3D visualizations adopt different types of depiction, i.e., 2.5D (also called pseudo-3D) that displays 3D on a 2D screen, and 3D (or real 3D) that presents 3D In stereoscopy or an immersive device (Çöltekin et al., 2016; Juřík et al., 2020). These types of depiction, along with the interactivity (static or interactive), affect the experience that users/participants undergo with the VGE. Several studies have explored the impact of these factors according to the performances and preferences of the users: interactive vs. static (Juřík et al., 2020); pseudo 3D vs. real 3D (Dong, Yang, et al., 2020; Herman et al., 2021; Juřík et al., 2020; van der Land et al., 2013); or 2D vs. 3D (Herbert & Chen, 2015; Liao et al., 2017; Seipel, 2013; van der Land et al., 2013). These studies highlight that real/pseudo 3D and interactivity may improve the accuracy of the users/participants depending on the tasks performed, but with an increase in complexity, participants tend to require more time to complete a task.

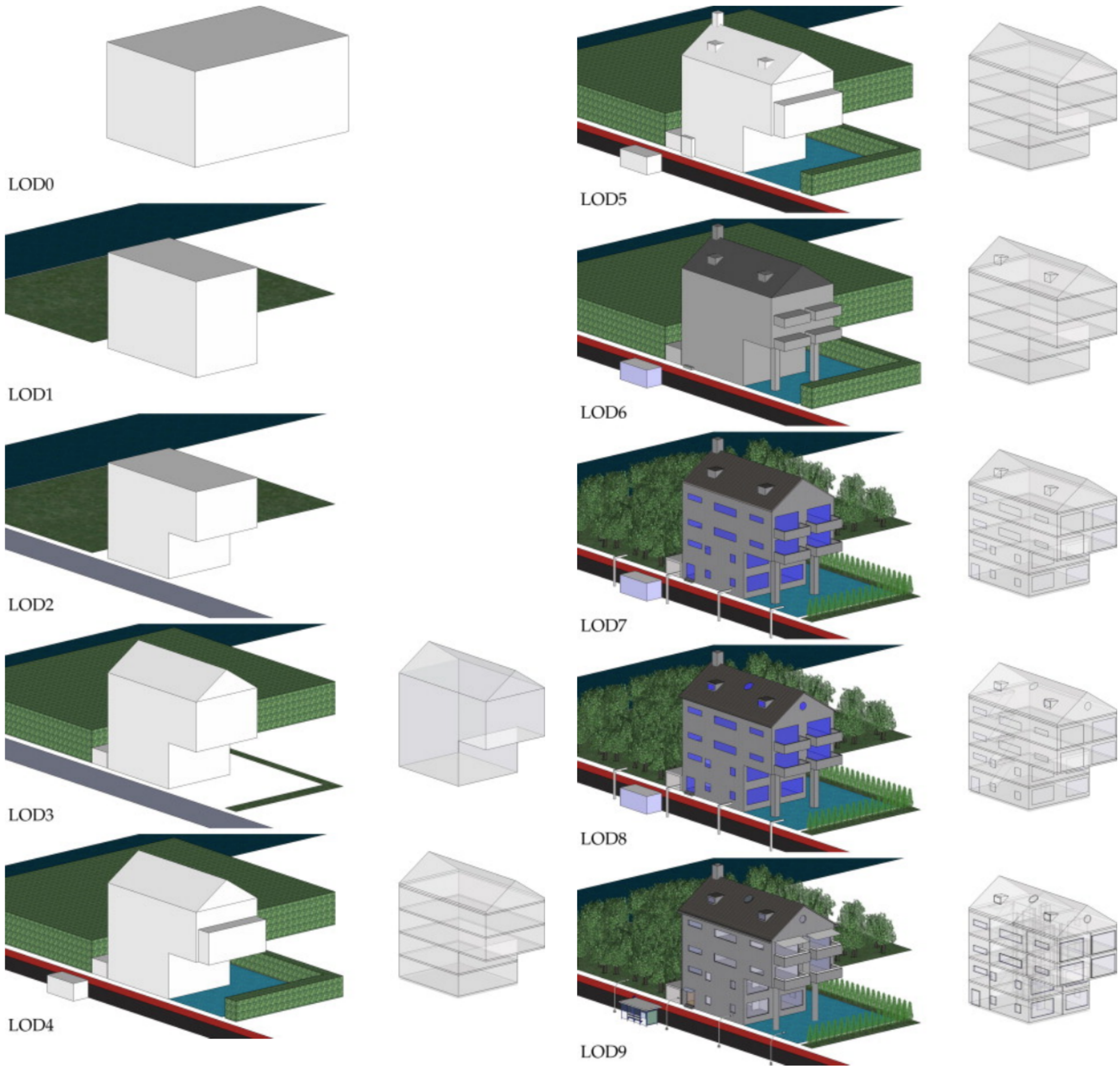


***Figure 2.3**. Illustration of the different* LOD for 3D city modeling defined by (Biljecki et al., 2014)

Human factors. Every individual will experience 3D and virtual geographic environments differently, due to their idiosyncrasies. The skills and abilities of the participants/users can enhance or hinder their consumption of interactive 3D visualization (Çöltekin et al., 2016), or any digital technologies (van Deursen & Mossberger, 2018). Each participant has specific socio-demographic characteristics (age, social status, sex, education, income, etc.) (Hoffmeyer-Zlotnik, 2016), skills and backgrounds (past experiences with a VGE, spatial abilities), and preferences. These elements are influencing how individuals perceive and experience the space surrounding them, leading to differences (Gailing & Leibenath, 2015); and these contrasting views are also true for virtual spaces (Stanney et al., 1998). Diverging perspectives may lead to misunderstanding, opposing opinions or beliefs while employing VGE. Skills and abilities based on socio-demographic characteristics also affect the performance of the participants/users while operating VGE; unequal performances with VGE lead to unbalanced opportunities in conveying participants' contributions to the approach, i.e., lack of access and insufficient inclusivity. Several studies have explored inequalities in using 3D or analog visualization techniques. Numerous characteristics have shown to be significant in the performance or behavior of participants/users while consuming these representations such as spatial abilities (Çöltekin et al., 2018), age (Hermann et al., 2020; Lokka et al., 2018), sex (Dong, Zhan, et al., 2020; Ugwitz et al., 2019), or previous experience (Burigat & Chittaro, 2007; Ugwitz et al., 2019). These inequalities lead to a unique response that is specific to a particular individual, and that needs to be considered when using 3D e-tools in urban participatory planning.

2.3.3. Applicability in Participatory Planning Approaches and Past Experiments

As early as 2011, E. Lange argued that the technological advancements in the previous years were sufficient to overcome the main challenges of 3D visualizations for urban planning, providing a new gateway for global growth (Lange, 2011). However, 3D technology by itself cannot initiate a shift in participatory practices, because it is not the only parameter considered. Urban projects are complex, and contingent on the individuality of the cities; therefore, participatory tools should be generic, flexible, and resilient enough to leverage participatory practices in planning (Dambruch & Krämer, 2014), yet the generalization of these tools is not fully achievable (Khan et al., 2014). Based on the versatility of practices several 3D participatory methods are suggested, such as comparing redevelopment scenarios in Kenya with ArcGis CityEngine[29] (Onyimbi et al., 2018), simulating build configurations following local urban plan directives, and confronting the configuration with urban dwellers based on an in-house software (Brasebin et al., 2016), a micro-scale 3D PPGIS platform (Sabri et al., 2016), sharing information about development proposals through a virtual globe (Wu et al., 2010), using a city model (or digital twin) to gather dweller feedback (White et al., 2021) or compare scenarios of implementation using GIS and CAD (Computer-Aided Design) models (Wanarat & Nuanwan, 2013). These heterogeneous methods demonstrate the versatility of 3D e-tools in participatory planning in terms of technologies, context, and tasks.

To emphasize even more the variability of the 3D practices, applied examples from the literature will be recovered, described, and discussed. A sample of twenty tools, tested with participants/users were collected and compared. This plethora of examples does not aim to replace an accurate systematic review of participatory projects in urban planning but aspires to provide an overview of practices, to identify apparent patterns. Table 2.1 shows the comparison framework used to describe the examples. This table describes four parameters that are crucial for the conduction of interactive sessions:

[29] https://www.esri.com/en-us/arcgis/products/arcgis-cityengine/overview

(1) **Localization**, which locates the participatory session from in situ (i.e., in the place under negotiation), to online or in-person (i.e., within a laboratory, workshop, or other).

(2) The **number of participants**, from a setting that allows only a few participants to large sessions which aggregate quantitative inputs from the urban dwellers.

(3) **Facilitator**, which reports if the participatory sessions were facilitated or not, digital facilitation can be implemented by explicative videos, asynchronous expert discussions, or an information guide showing to the users/participants how to interact with the tool.

(4) **Task complexity** that assesses the difficulty of the interaction with the 3D tool (cognitive load), from no interaction to complex, if the participants have created in 3D a new layout of a public place; easy is related to simple navigation within the virtual environment, the consultation of information boxes or the vote for a specific alternative, medium concerns geo-discussions through the 3D model, or sketching of virtual elements.

The additional cells of Table 2.1 display information on the authors and year of publication, a brief description of the setting and interactive session, and the technology that has been adopted.

The adopted color code does not imply any hierarchy within the parameters. They have been selected to facilitate their memorization will browsing the following examples.

Number and Title		**3D medium**	
Authors	**Description**		
Localization 🔴 *in situ* 🔵 *online* 🟢 *in-person*	**Nb participants** 🟢 *< 15* 🟡 *< 100* 🔴 *> 100*	**Facilitator** 🟢 *Yes* 🔴 *No* 🔵 *Digital*	**Tasks complexity** 🔴 *Complex* 🟠 *Medium* 🟡 *Easy* 🟢 *No interaction*

Table 2.1. *Illustration of the framework used to present the different examples*

Description of the selected use cases.

1. Bottom-up static visualization		Images from 3D real-time model broadcast on a screen	
(Lindquist, 2007)	*City officials were invited by a community group to discuss a proposal for the development of the city. The session was conducted by neutral facilitators and was enhanced by the broadcast of a 2D static portrayal of the project (recorded from a real-time virtual geographic environment).*		
🟢	🟢	🟢	🟢

2. CommunityViz		CAVE-based medium based on three screens	
(Salter et al., 2009)	*Participants (professionals) could discuss the implementation of different density scenarios while being immersed in a CAVE. A 2D depiction of the alternatives was first explained, then the planning area was explored and discussed according to the alternatives. Facilitators were present to ease the interactions. Certain indicators were portrayed to support the decision-making.*		
🟢	🟢	🟢	🟢

3. Decision support tool in the HIVE environment		Immersive VR using stereoscopic 3D	
(Isaacs et al., 2011)	*The HIVE consists of large projecting screens, where two scenarios under comparison are portrayed in stereoscopic 3D; a less immersive depiction is still possible within a normal computer display. The project aimed to compare these two scenarios according to their sustainable values and select the best alternative.*		
🟢	🟢	🟢	🟡

4. Multi-stage 3D participation		Virtual globe	
(Hu et al., 2015)	*Participants were asked to contribute to an urban project during its different stages (ideas generation, evaluation, etc.) within an online virtual globe. One group of students co-designed alternatives within the VGE, while another student group discussed the alternatives with 3D geo-discussions.*		
🔵	🔴	🔵	🔴 / 🟠

5. Ipcity		Mixed reality - tangible table & VGE projected on a screen	
(Özdirlik & Terrin, 2015)	*Participants are gathered within a tent located at the place under transformation. At the center of the tent lies a table with geometric wood volume. Participants co-design the place by arranging the volume. A screen displays in real-time the designed place in digital 3D (from the arrangement of the wood forms). A window is also open in the tent to visualize the current stage of the place under negotiation.*		
🔴	🟢	🟢	🔴

6. VisAsim		Immersive setup, using audio and video	
(Hayek et al., 2017)	*The authors described a setup, presented during an exposition, to inform the public about the impact of a wind farm within the territory. Participants were in front of a screen and surrounded by speakers simulating contextual sounds. Two scenarios were portrayed in two distinct landscapes, at various distances from the wind turbines, and under a few wind conditions. It was also possible to experience this scenario with a tablet and headphones.*		
🟢	🔴	🔴	🟢

7. Create, experience, and live in 3D virtual environments		Web applications based on a game engine	
(Alatalo et al., 2017)	*Two applied cases were described. The authors first present the use of a web 3D application, implemented with a game engine, to co-design areas under development (online or in-person), and to explore different scenarios. The second example was conducted during an architectural challenge. The alternatives were available online, but no information was available on how the contributions (comments and votes) were collected.*		
🟢 / 🔵	🔴	🟢 / 🔴	🟠 / 🟡

8. Vote for a preferred scenario		Immersive VR & web non-immersive VR	
(van Leeuwen et al., 2018)	*Three design scenarios were submitted for voting by the population. Each solution was accessible without guidance online through a website, or on-site at several locations within the city, directly on paper-based maps or in immersive virtual reality with head-mounted devices. Participants could select different designs to observe and navigate the model in a Google Street View-based interaction.*		
🟢 / 🔵	🔴	🟢 / 🔴	🟡

9. 3D questionnaire for non-local participants		Web application	
(Onitsuka et al., 2018)	*Non-local stakeholders were asked about the quality of a landscape that they did not visit. The virtual landscape was shared online, along with a questionnaire. Users had to orient the 3D model and write comments on an annexed file to reply to the questions.*		
🔵	🔴	🔴	🟡

10. Land.Info		Web application based on a game engine	
(Saebom Kwon et al., 2019)	*A co-design platform that allows placing natural and human-made furniture in a virtual environment. Each element can be assessed in terms of environmental and financial gain/cost. After an in situ visit of the place under negotiation, and paper-based explanation and exchanges, groups of three participants co-designed a future place via the platform, which was controlled by a facilitator.*		
🟢	🟢	🟢	🔴

11. 3D geo-visualizations for flood risk		Immersive VR application	
(Jacquinod & Bonaccorsi, 2019)	*The authors shared a retrospective of eight years of action-research projects using 3D visualizations in flood risk management. Only the two last years will be discussed in this use case, in which the authors engage the local population to raise awareness with immersive technologies. Participants could visualize in situ the virtual environment, through two types of devices (tablet or immersive). Inputs from the participants were not expected*		
🔴	🟡	🟢	🟢

12. Virtual Globe for urban evolution		Virtual globe	
(Lafrance et al., 2019)	*Five scenarios were developed using a virtual globe in a participatory context. The authors mentioned only two examples. Following a video presenting the platform in five minutes, participants were able to contribute online. The platform is used as a 3D geo-questionnaire. The first scenario describes the creation of bike lanes (via drawing lines) according to connectivity; the second portrays the addition or the removal of new buildings by the participants according to the evolution of the district in terms of timeline and population density.*		
🔵	🔴	🔵	🟠 / 🟡

13. Co-design on a tactile screen		Tactile table, designed via a game engine	
(Faliu et al., 2019)	*Participants were required to co-design a place through a tactile screen device. During a workshop, participants can add virtual elements (available from a toolbox) to design a place. The tool is developed via a game engine, and the result of the co-design activity can be visualized with a head-mounted device. Feedback can be submitted within the immersive view.*		
🟢	🟢	🟢	🔴

14. Asymmetrical immersive co-design		Immersive VR-based on a game engine	
(Chowdhury & Schnabel, 2020)	*A co-design process where one of the participants wears a head-mounted device and interacts with the 3D models. Other participants sit in front of a screen and interact orally with the participant interacting with the virtual model and in charge of the design controls*		
🟢	🟢	🔴	🔴 / 🟢

15. XYEarth		Virtual globe	
(Yu et al., 2020)	*The 3D platform was used through three distinct phases that were organized through in-person workshops. The first was to recreate the historical development of the area under negotiation, thanks to the collection of local knowledge from the urban dwellers. This recollection was supported by a 3D visualization of the place and a discussion with the citizens. The second aimed at identifying the issues related to the development of the place, notably by geolocating these issues with the participants on the virtual tool. The third phase addressed the identified issues through discussion, conflict resolution, and refinement of the development project.*		
🟢	🟢	🟢	🔴 / 🟢

16. 3D Geo-survey		3D map survey [Maptionnaire]	
(Eilola & Fagerholm, 2021)	*Participants were consulted on the urban development of a city center block. From an online survey, participants could explore the project and information boxes, and pin markers on the 3D model to provide geo-referenced comments.*		
🔵	🔴	🔴	🟡

17. Quick Urban Analysis Kit		In-house web application	
(Müller, 2021)	*A web platform, which promotes the design of a space by placing various non-editable elements in the virtual environment. A toolbox is present on the right side of the screen; users have to drag and drop the objects to add them to the project.*		
🔵	🔴	🔴	🔴

18. A 3D survey		Virtual globe	
(Würstle et al., 2021)	*Participants had to answer questions from a 3D questionnaire about the future development of a district. To answer, participants could visualize the area under discussion in 3D, and consult information boxes. Socio-demographic data was not required.*		
🔵	🔴	🔴	🟡

19. Immersive scenario comparison		Immersive VR-based on a game engine	
(Newell et al., 2021)	*The authors described an immersive tool to compare three scenarios about the development of a district. The three scenarios were articulated around the density of the housing. A first focus group was organized by the authors of the study, which aimed at improving the tool. Then, an open house event was conducted. The public was free to try the tool and get immersed in the different scenarios. The participants' contributions were collected after the experiment through paper-based surveys.*		
🟢	🟢	🟢	🟡

20. Perceived landscape quality		Static images recorded from 3D models	
(Salak et al., 2022)	*The participants had to select a scenario for the implementation of energy infrastructure, depicted on a digitally generated visualization, from two possible alternatives. A web app depicted a static image of these scenarios. The goal of the experiment was to identify conflictual areas by implementing the energy infrastructures*		
🔵	🔴	🔴	🟡

From the comparative table here before and their summary (Table 2.2), it appears that an online setting is linked to more participants and easier tasks, which is in line with the idea that the wider the audience is, the shallower the engagement gets (Haas Lyons, 2017). Furthermore, it seems that participatory sessions that exploit 3D tools involve either a small number of participants or a considerable number. Moreover, digital tools based on 3D visualization are invariably limited to a practice that is linked to an indoor place, such as a workshop location, a lab, or the participant's home. Therefore, the place of the participatory session is distinct from the place under negotiation and transformation, which implies that the subjects addressed during the session are regarding a distant place that may be difficult to apprehend. To merge these two distinct locations, Gill & Lange suggest getting these virtual environments "out of the lab", by describing a prototype of a 3D e-tool working in situ with a mobile phone (Gill & Lange, 2015). Some attempts have demonstrated promising results with a head-mounted VR device used in situ (Pouke et al., 2019). Technical challenges are still to be addressed, especially with the bandwidth performance, which is not always efficient in an outside setting, but the development of 4G and 5G cellular networks is revolutionizing the domain, hence promoting new opportunities for the implementation of in situ 3D participatory e-tools. Furthermore, most of these examples describe a participatory 3D tool applied to only one context in one specific project. In these studies, rare information is available on the success (or failure) of the project enhanced by the 3D medium, the following implementations of the 3D tool in another project, or the subsequent redesign of the 3D tool that takes into account the feedback collected.

Some variables have a count superior to 20 (the number of examples) because some sessions regrouped more than one setting.

[N] Localization	[N] Nb participants	[N] Facilitator	[N] Tasks complexity
[2] 🔴 *in situ*	[9] 🟢 *< 15*	[11] 🟢 *Yes*	[7] 🔴 *Complex*
[9] 🔵 *online*	[1] 🟡 *< 100*	[10] 🔴 *No*	[3] 🟠 *Medium*
[11] 🟢 *in-person*	[10] 🔴 *> 100*	[2] 🔵 *Digital*	[9] 🟡 *Easy*
			[6] 🟢 *No interaction*

Table 2.2. *Findings based on the examples that aggregate the different variables related to the parameters*

2.4. Stating the Gap

Urban participatory approaches are at the same time accurately defined and insufficiently understood because of their various contexts of application. These opposing views lead to complex challenges in their implementation, which often result in the creation of poor interactive areas that do not fully comply with the democratic values that are promoted by these approaches. Digital technologies, which include GIS and VGE, aim at transforming interactive sessions into more efficient and meaningful areas. However, the added value of (3D) digital tools also introduces a new layer of complexity to the design of urban participatory practices. Digital tools and 3D technologies are still recent for participatory planning approaches; thus, their impact on the practices and the interaction between stakeholders is not fully understood. The implementation of modern urban participatory approaches is, therefore, not encouraged due to the perceived complexity of the design elements to be considered. As a consequence of these concerns, the practitioners do not adopt a proactive stance and tend to implement digitally limited urban participatory approaches.

Chapter

3. Research Objectives

List of abbreviations for the chapter:

RG: Research Goal
VGE: Virtual geographic environment

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The theoretical context described in the previous sections highlights today's requirement for citizens' involvement in urban planning. Urban projects are increasingly complex. The institutions with their administrative and distant understanding of the place face decisive challenges to plan better, more sustainable cities. An appealing solution to address these challenges is the engagement of the population in the planning process. However, collaborating in a context where urban dwellers are hesitant to trust local authorities, and the authorities that are not fully committed to participatory approaches, may turn unproductive. Digital participatory tools were developed to transform the mode of interactions between the public and the authorities, and ultimately rebuild trust between these stakeholders. From digital technologies, 3D visualizations were soon acknowledged as a valuable medium to enhance the understanding of sophisticated urban issues, and to articulate the negotiation about planning. However, authorities appear to be skeptical about the adoption of digital tools (including 3D) (Ahmed & Sekar, 2015), because despite the opportunities that they offer, digital tools are complex to implement, and their added value to participatory processes is not entirely understood.

As mentioned in chapter 1, participatory sessions are articulated around a medium that enhances the interactions between the stakeholders attending the session. The interactive sessions can be very different in terms of settings because they are based on three highly versatile aspects: the practices (Where?), the participants (Who?), and the medium (What? and How?) (Figure 1.4). To be meaningful and productive, interactive sessions have to consider these three aspects mindfully. My Ph.D. research, articulated around these aspects, offers a fresh perspective on four focuses (practices are divided into two parts: current practices and their future). The following sections describe these four focuses and connect them to the publication related to this Ph.D. research.

3.1. Current Practices

The third dimension and its applicability to urban participatory e-planning do not seem to be fully explored. Several studies in the scientific literature focus their lens on highly specific use cases. Two issues can be highlighted from this particularity: (1) the technological settings mentioned in the studies relate to a very precise context, population, and project, therefore, the findings are hardly generalizable and exploitable to other projects; (2) the studies focus on academics' perspectives and inquiries, which can often be distant from the ones of the practitioners. The multiplicity of urban projects results in a "*technical pluralism*" (to quote Schrock, 2019) of participatory solutions, where identifying the best alternative for a hypothetical project is laborious. Therefore, my thesis aims to **understand better the participatory practices, both applied and theoretical**, that are adopting digital 3D to generate interactions between stakeholders. This knowledge foundation aims at identifying challenges and typical settings, which can be reused in improving participatory practices.

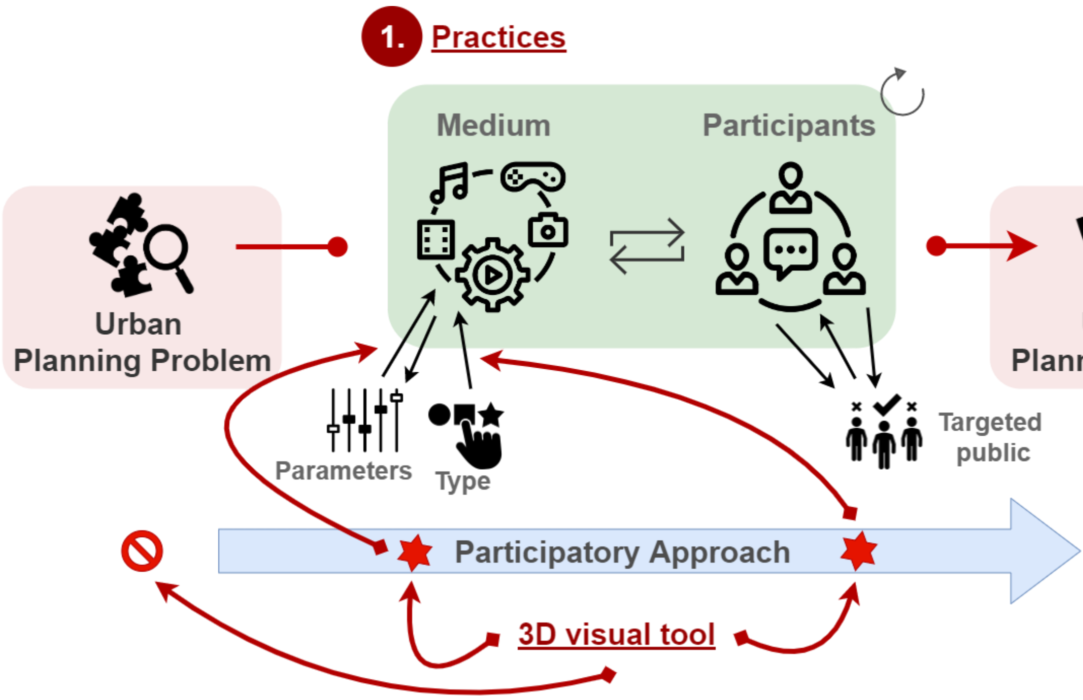

Figure 3.1. *Illustration of the research objective about the practices of 3D mediums in urban participatory e-planning. A 3D medium is not always suitable for a specific participatory approach or can be implemented with different parameters at different moments of the approach*

The practices involve the comprehension of current applications of 3D tools in urban participatory projects and the assessment of the quality of these applications. The investigation of the current practices of 3D visual tools illustrates different modalities for the engagement of the population. Considering 3D visualizations as a participatory medium, these tools promote the interaction between stakeholders. However, according to the use context, the settings of the interactive session, and the targeted public, 3D may sometimes be irrelevant, and its adoption can lead to enhancing or hindering the contributions of the participants. Specific moments of the participatory approach could require (or not) the use of 3D visualizations under a particular setup (type and parameters). Figure 3.1 summarize graphically the investigation suggested by the focus on current practices.

Related Research Questions.

RG1.1. Can typical practices be identified in urban participatory planning that adopts 3D visualizations? How are 3D visualizations applied in these approaches?

RG1.2. What are the bottlenecks in adopting 3D visualizations in urban participatory practices?

Complementary research questions

RQ1.a. Is the adoption of 3D visualizations in urban participatory planning evolving over time? Did the COVID-19 pandemic impact these practices?

Link to the publications.

To address these objectives, Paper A assesses the characteristics of the adopted 3D visualizations in applied projects recovered from media coverage. Furthermore, Paper B presents a similar analysis in light of challenges on technical and contextual parameters based on the scientific literature. These two articles anchor the current knowledge and application of 3D visualizations in urban participatory planning.

3.2. Participants

The role of the affected citizens in 3D urban participatory e-planning varies according to the practices. Also, participants have their preferences, background, and skills, which perpetually shape the practices and the selected medium. One of the goals of participation is to promote democratic values. Questions about legitimacy, trust, and inclusivity should be, therefore, at the core of every design of the participatory session. However, any adopted medium, including VGE excludes parts of the population, which means reducing the inclusivity of the approach. Who participates and who is excluded from participatory sessions have a strong impact on the outcomes of the approach. Therefore, identifying the affected population and comprehending how the selection of a medium is shaping the participants' characteristics is crucial during the design of a participatory approach. My Ph.D. research investigates these dimensions by **assessing the mechanisms (contextual and technical) that lead individuals to take part in a participatory approach** using a 3D medium.

The participants are the core of any participatory approach. The issue of representativeness discussed in chapter 2 implies a complex relationship between urban dwellers, the targeted public, and the actual participants. This relation is affected by several parameters such as preference, skills, and socio-demographic characteristics. The selection of a participatory medium is never neutral and affect significantly the observed gap between the population and the specific individuals, which are attending an interactive session. The focus on the participants investigates the process that creates this gap. The assessment of the dynamics, which leads to engaging specific profiles of individuals, could help to reduce this gap, hence encouraging participatory practices to be more inclusive. Figure 3.2 summarize the focus on the participants graphically.

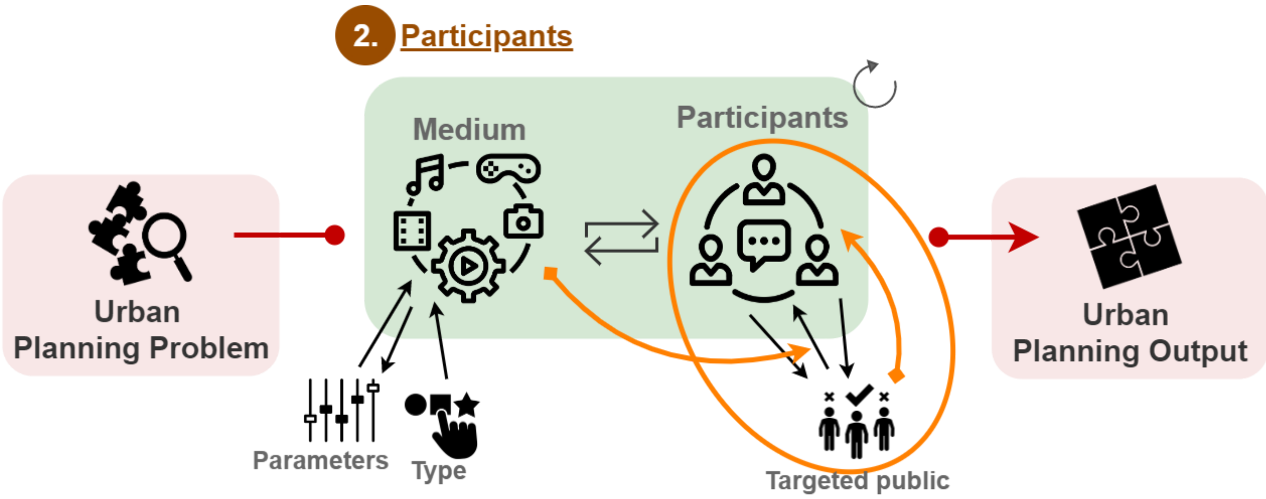

Figure 3.2. *Illustration of the research objective about the selection processes induced by the design of interactive sessions. There is a gap between the participants that are mobilized in an interactive session and the targeted public that is identified by the authorities. This selection process is affected by the adoption of a specific medium*

Related Research Questions.

RG2.1. - What proxy can be applied to evaluate the success of a participatory tool in mobilizing the right targeted public?

RG2.2. - How is the adoption of an online or offline medium impacting a participatory session and its engaged participants?

Link to the publications.

To better understand the gap between the participants and the affected population. Paper C provides a framework based on access dimensions, which aims at evaluating the suitability of a participatory medium from the perspective of urban dwellers. This framework is initiated from the observation that designing a good medium to engage the population is challenging (Paper B), which leads to adopting a variability of settings to implement interactive sessions (Paper A). Therefore, the framework introduced in Paper C could help to understand better the conditions that encourage specific participants to be involved.

3.3. 3D Medium

An understanding of the interactions between the participants and the 3D medium is essential for improving participatory approaches. The collection of citizens' contributions is performed through interacting with a medium. However, the design of these mediums is complex and dependent on several factors. Digital technologies provide a toolbox that can be mobilized through various settings, which should be designed to improve the interactive experience with the medium. In the case of 3D, several studies investigate how its different representations can impact the experience of the participants/users. Tasks, representations (in terms of style), and devices have been acknowledged to affect the interaction between the user/participant and the 3D medium. Following these studies, my Ph.D. research aspires to **determine the nature of the interactions in terms of performance and behavior between participants and a 3D medium** through participatory tasks.

The 3D medium is the second crucial element of this Ph.D. research. The 3D medium is investigated as described in Figure 3.3. Several external factors (as explained in the practices) are affecting the design of 3D mediums, i.e., their type and parameters. The design of a 3D medium could facilitate the understanding of the project, mobilize the targeted public and ease the interactions with the participants. However, the implementation of an efficient design is not straightforward, because of the multiple possible combinations of parameters, types, contexts, and participant profiles. Through the investigation of the 3D medium, the impacts and synergies of all these factors aimed to be identified, which could lead to the design of better 3D mediums.

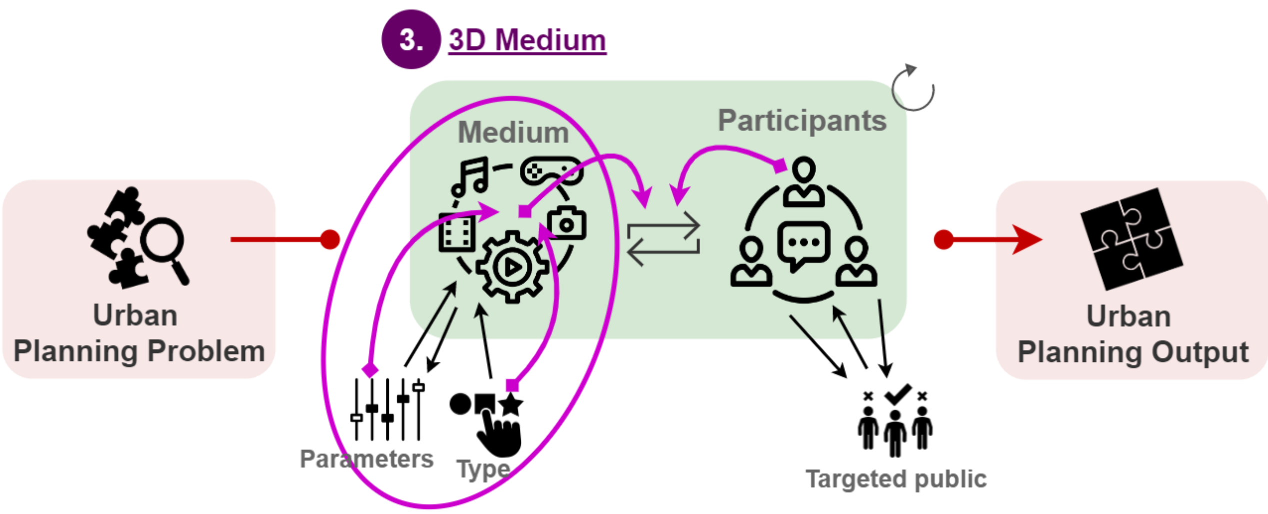

Figure 3.3*. Illustration of the research objective about the impact of the adoption of a 3D medium in urban participatory e-planning. Parameters and types of a 3D medium affect the interactive experience of the participants*

Related Research Questions.

RG3.1. - How do parameters and types of a 3D medium affect the experience of participants during an interactive session? What 3D settings could enhance urban participatory e-planning approaches?

RG3.2. - Do the participants develop specific behaviors or strategies while interacting with a 3D medium? If so, which ones?

Link to the publications.

The investigation of the 3D medium is discussed through a user experiment described in Paper D and Paper E. The experiment is based on scenarios that use specific parameters employed in current participatory practices observed and described in Paper A. The study evaluates how different 3D visualizations affect the understanding of virtual environments and their exploration through simple interaction.

3.4. Future Practices

Several hindrances pace current participatory e-practices, which emphasize the need to transform and improve practices of 3D urban participatory e-planning tools. The projects described in the scientific literature portray the use of digital tools around three main categories: (1) at home through a computer (or a smartphone); (2) in a specific location to experience state-of-the-art technologies such as AR or VR; and (3) in typical participatory sessions such as a workshop or public hearings. Despite technological optimizations and increasing bandwidth, participatory sessions are principally limited to an indoor place distant from the place under transformation, which limits the scope of the discussions. In 2015, the idea of getting participatory sessions “out of the lab”, i.e., in situ, was argued (Gill & Lange, 2015). However, only a few projects attempted to design these in situ approaches. This Ph.D. research aims at **developing new practices that could use the full potential of 3D technologies** to enhance urban participatory e-planning.

The design of an interactive session that stimulates the involvement of urban dwellers is challenging. However, only rare attempts try to encourage a change of established risk-free current practices. These dynamics lead to designing approaches, which are limited. The use of 3D visualizations is restricted to a simple setup, which passively engages the participants in front of a screen and remotely from the area under transformation. Therefore, I suggest a new approach that immerses *in situ* the participants in the future project under discussion.

Related Research Questions.

RG4.1. - Which 3D settings in participatory e-planning projects could improve the mobilization of the participants and comply with the democratic values (inclusiveness and representativeness) promoted by those approaches?

Link to the publications.

The exploration of future practices of urban participatory e-planning is explored in Paper F. The approach that is suggested is based on the conclusions of all the mentioned articles. A prototype has been implemented and tested with participants. The prototype provides a user-friendly and straightforward interaction to any participants that would like to contribute to a project.

Chapter

4. Implemented Prototypes: Methods, Technologies, and Experiences

List of abbreviations for the chapter:

GIS: Geographic Information Systems
LOD: Level of Detail
RESTful API: REpresentational State Transfer Application Programming Interface
HTTP: Hypertext Transfer Protocol
DEM: Digital Elevation Model
VGE: Virtual Geographic Environment
PPGIS: Public Participation GIS
CGI: Computer-Generated Imagery
IP: Industrial Park

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This transdisciplinary research encompasses several domains, such as social sciences, urban planning, geomatics engineering, human cognition, and participatory sciences (see the two previous chapters). To address the research questions that are bridging these domains, a mixed research approach was employed. Interviews, active participation, and observations were extensively adopted in this research. Formal and informal interviews were conducted with cartographic and cadastral offices, urban planning departments of several municipalities, and a few consulting firms active in urban participatory planning. Active participation was performed through discussions with three municipalities on the adoption of some of the prototypes that were implemented during this Ph.D. research, the participation in webinars about the use of 3D technology (called *Webinar 3D et geospatial*[30]), and the participation in workshops organized by a network of practitioners[31] working on participatory thematic. Observations were conducted through active participation, and the opportunity to attend two interactive sessions of the same participatory approach, one using a 3D medium and the other not. The competencies built during these three described methods were described in Paper C and in the general discussion section of this Ph.D. research (chapter 11). Moreover, a summary of the discussions with the municipalities is reported in this chapter (Section 4.3).

[30] https://github.com/VCityTeam/MAGIS-AP3D/blob/master/Media/README.md
[31] https://reropa.ch/

Extensive research has been conducted in the media and in the scientific literature to better assess how 3D visualizations are perceived and practiced by academics, but also by the practitioners themselves. Building knowledge about their use supported an enhanced comprehension of the assets and challenges inherent to 3D in participatory planning. The conclusions of these approaches are reported in Paper A, which identifies applied practices through press coverage, Paper B, which highlights challenges in using 3D tools, and Paper C, which suggests a new approach to undertaking the selection of an interactive medium for urban e-participatory planning.

In addition to these methods, two user experiments were conducted to assess the practice of 3D mediums in a participatory planning context through the evaluation of user perception regarding the Virtual Geographic Environment, and the usability of these tools in a scripted context. These explorative experiments were conducted with two in-house solutions. The first was a user study, coordinated online in the context of the COVID-19 pandemic, aimed at assessing the performance of users with Virtual Geographic Environments through the completion of tasks related to urban participatory settings (identifying the highest building, the visibility of certain elements, the link between 2D and 3D perspectives). The related findings are developed through Papers D and E. The second experiment aspires to test the usability of one of the developed prototypes, resulting from prior identified challenges. The prototype was tested through a scripted scenario. The results of this study are portrayed in article F.

These specific methods will be described in detail in the corresponding chapters. The mixed research approach developed in this Ph.D. thesis follows one overall method based on the implementation and evaluation of consecutive prototypes.

4.1. Research Approach Through the Evaluation of Prototypes

Several prototypes of 3D participatory platforms (6 in total) were implemented throughout this Ph.D. research. Their developments aim at challenging the different notions introduced in this research with practitioners or future users, i.e., potential participants. The development of the prototypes, i.e., the research approach, was articulated around three phases (Figure 4.1). These phases mimic the *agile* practices that are often adopted in software development. Agile practices are based on three steps define, build and release:

Conceptualization and Framing phase (define).

In this phase, different notions, concepts, hypotheses, or ideas were brainstormed with peers, colleagues, participants, or experts. Furthermore, extensive research was conducted in the media and in the scientific literature to understand better how 3D visualizations are perceived and practiced by academics, but also by the practitioners themselves. Moreover, observations were conducted through the opportunity to attend two interactive sessions of the same participatory approach, one using a 3D medium and the other not. Building knowledge about their use supported the identification of challenges, opportunities, and bottlenecks inherent to 3D in participatory planning.

Implementation and Development phase (build).

This phase aspires to translate the identified challenges, opportunities, and bottlenecks into hypotheses that can be technically implemented within a prototype. During this phase, six prototypes were developed along with one in-house 3D survey. The prototypes and their implementation will be further described in the next section.

Testing and Evaluation phase (release).

This phase aims to test and evaluate prototypes that were implemented. Two methods were mobilized for this phase. On the one hand, two user experiments (with a total of 150 participants) were conducted to test the validity of the prototypes and, by extension, their implied hypotheses. On the other hand, the prototypes were discussed and presented to peers, practitioners, and city officials. Formal and informal interviews debating the use of 3D in participatory processes and the prototypes were conducted with cartographic and cadastral offices, urban planning departments of several municipalities, and a few consulting firms active in urban participatory planning. Active participation was performed through discussions with three municipalities, the participation in webinars about the use of 3D technology (called *Webinar 3D et geospatial*[32]), and the participation in workshops organized by a network of practitioners[33] working on participatory thematic. Through this phase, I could identify new challenges or notions that needed more investigation, hence providing material for the conceptualizing and framing phase.

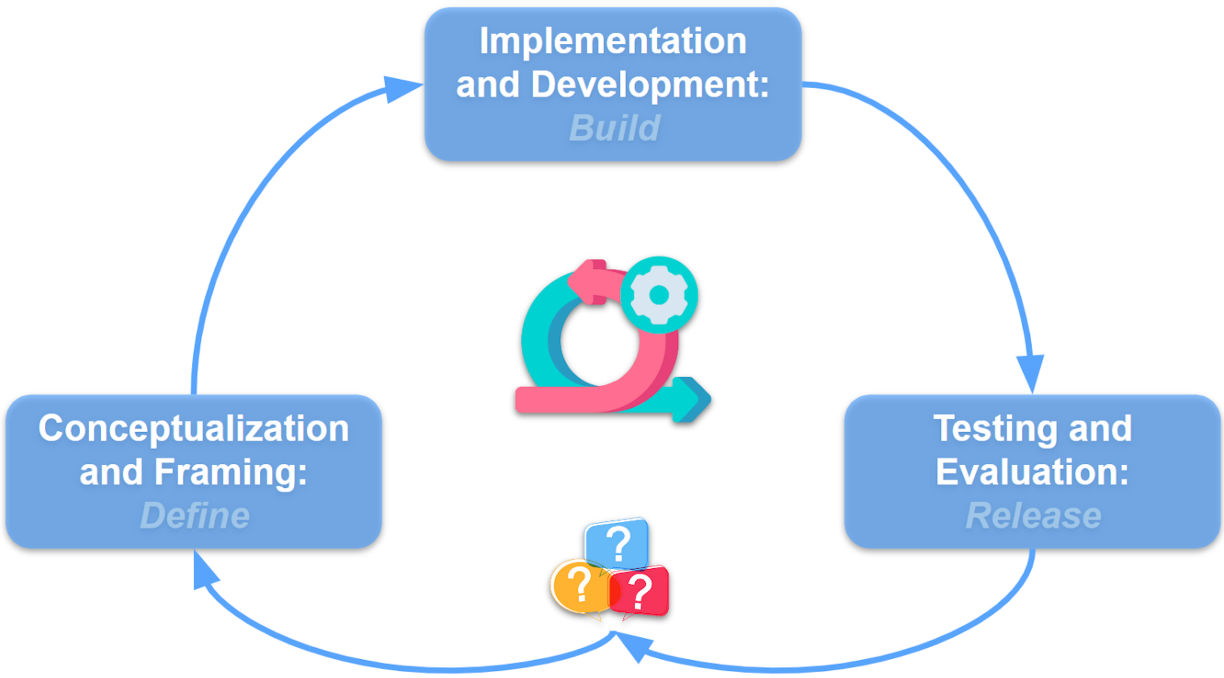


***Figure 4.1**. The overall method adopted in this Ph.D. research is mimicking the agile approach often implemented in software development. This method aims at tackling the various objectives and the research goals*

[32] https://github.com/VCityTeam/MAGIS-AP3D/blob/master/Media/README.md
[33] https://reropa.ch/

4.2. Development of Prototypes

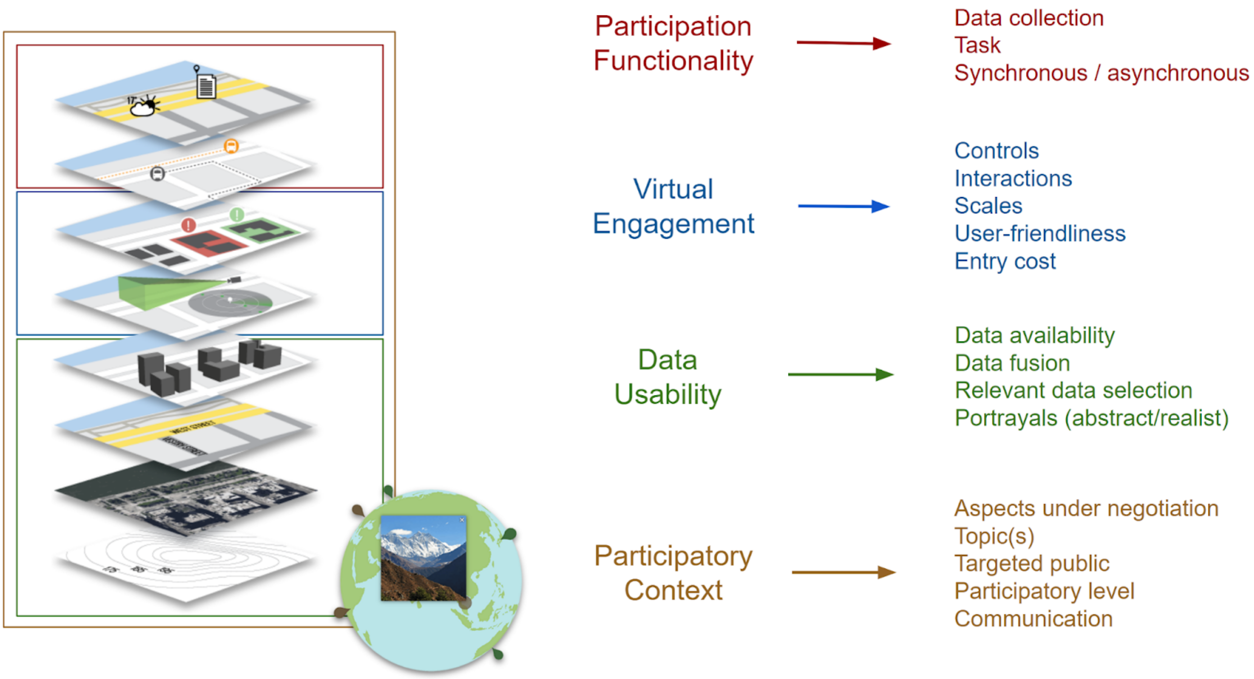
4.2.1. Technical Choices and Details

All the prototypes are based on a web application, available directly in the browser, without a need for an installation prior to using the platform. Therefore, participants could immediately contribute through the tool, without having to execute any steps before accessing the main functionalities. This absence of complication aims at facilitating access to the platform by limiting its entry cost. The technology adopted is a virtual globe, with the open source CesiumJS[34] library. The selection of a virtual globe to base the development of the web application has several advantages. First, this technology is already well-known to the broad public notably thanks to Google Earth. Second, virtual globes are highly flexible, which allows them to be adopted in various contexts. They represent the entire globe; therefore, the functionality developed at one specific place can be exported flawlessly to another, if the data are available. Also, they provide an out-of-the-box tiling system that enables users/participants to navigate seamlessly through the virtual environment without having excessive download time. Third, virtual globes are a powerful tool for aggregating (spatial) data. The aspect of spatiality is crucial for urban projects that are anchored in the territory. Therefore, using a tool that supports this dimension by default is practical. In addition, participatory planning tends to fuse several types of data (source, format) that can be easily aggregated within the virtual globe, shaped as layers like GIS (Figure 4.2.).

The contextual data was recovered and portrayed from SwissTopo[35]. All of the prototypes were using the digital elevation model (DEM), a basemap, 3D trees, and buildings modeled in 3D. Through this data, all buildings of Switzerland were available in LOD2 in the prototypes, which allowed the creation of accurate (abstract) contextual surroundings for the urban projects (see the prototypes below). The data provided by SwissTopo has been open since the 1st of March 2021, which means that it could be used free of charge for any kind of application. This data was directly recovered in the application through SwissTopo's RESTful API (REpresentational State Transfer Application Programming Interface). RESTful API is a web service that allows access to data through HTTP (Hypertext Transfer Protocol) requests. In other words, this service allows users to read, update, create or delete (GET, PUT, POST, DELETE), data from a remote server. Virtual globes facilitate access to data through this type of communication.

Strategies or participatory tasks had to be implemented to collect the contributions of the participants. Different tasks and functionalities will be described in the next section. These tasks were developed in VueJS[36], which is a JavaScript framework often used to build front-end applications. The idea of the front-end is related to elements that are directly manipulated by users. The interactions and contributions of the participants were recorded and saved in a database. The prototypes and more technical details are available on github[37]: https://github.com/thibaud-c.

[34] https://cesium.com/platform/cesiumjs/
[35] https://www.swisstopo.admin.ch/fr/home.html
[36] https://vuejs.org/
[37] https://github.com/



<u>Figure 4.2.</u> *Schema shows the questioning adopted in the design of the participatory e-platform prototypes. The categories on the right of the figure describe the key challenges addressed by my approach to designing a VGE for participatory planning. Each category is related to specific aspects*

Figure 4.2. summarizes the thinking process and different concepts used to design the prototypes. The contextual data (data usability) aims to orient and guide the users/participants within the virtual environment. This step is critical because 3D data is difficult to find or not always available. Moreover, challenges about the fusion of different types of data and how to represent them (filtering and style) need to be addressed in order to facilitate the interaction with the virtual environment and limit the cognitive load to create the best possible experience for users/participants. Virtual engagement is related to technical issues such as the creation of simple interactions, which facilitate engagement. Also, user-friendliness and entry cost are addressed in this second layer. The objective is to design a simple captivating action that could commit the participants/users to contribute. Participation functionalities add platform-specific insights related to the participatory approach, such as the nature of the data to collect and the implementation of the task to manage it. In addition, issues about communication between participants or experts are addressed in this layer. All of these layers are encompassed in the participatory context that is associated with social, political, financial, and cultural aspects of the participatory approach. The project is also considered, with its aspects under negotiation, the targeted public to discuss these aspects, and the level of involvement. Communication, promotion, and advertisement of the participatory approach are included in this layer as well, and should not be neglected. Informing urban dwellers about the participatory approach, the project, the expected outcomes, and the processing of participants' contributions could improve the participants' perception of the approach, or build trust, which may lead to more engagement.

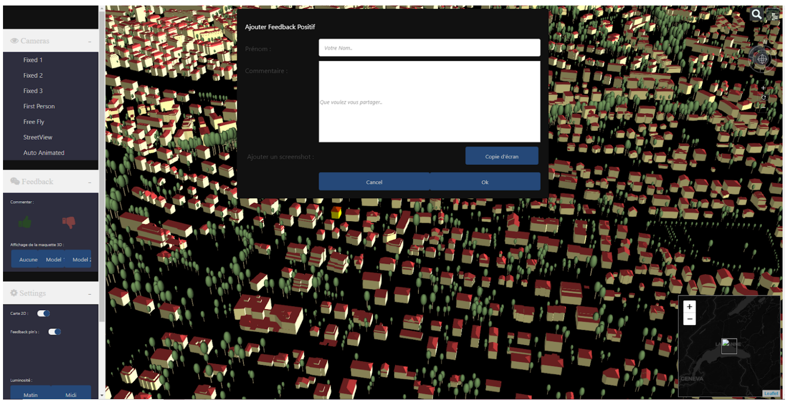
4.2.2. Prototype Descriptions

Throughout my Ph.D. research, I developed six main prototypes that are described hereafter. Each of these prototypes is based on the technologies and data mentioned in the previous section. The description of the prototype contains a screenshot portraying the appearance of the platform and a report of the main implemented functionalities.

Prototype 1.

A panel on the left side of the platform with the entire set of participative options was visible at all times. A 2D map with a small level of zoom was also portrayed on the bottom right to facilitate the orientation of the participants/users. Pre-recorded locations were implemented to ease the complexity of manipulating the virtual globe. The participants could compare architectural designs and add geo-referenced comments containing a positive or negative attribute, in addition to a name, body, and snapshot of the view that was seen at a specific time.

In the screenshot, the basemap of the globe was unfortunately not visible but should have been present.



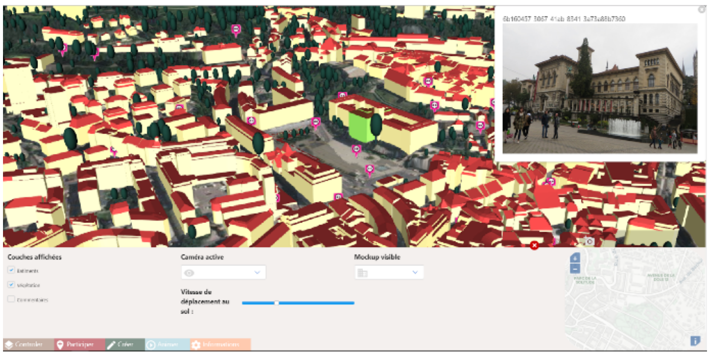
<u>Main functionalities:</u>

- Add geo-referenced comments
- Pre-recorded points of view
- Visualize simple 3D models
- Shadow simulation
- Compare architectural design and vote

<u>Figure 4.3.</u> *Screenshot of the first developed prototype and description of its main functionalities*

Prototype 2.

In this second platform, the panel was moved to the bottom of the screen with the 2D map still embedded in the bottom right. Categories were added to facilitate the navigation between the participatory options. Layers could be activated or deactivated (e.g., 3D objects, basemaps). A first-person immersion was also implemented where the camera was locked at 1.80 m to simulate human height, and the controls were switched to a keyboard and a mouse to look around. Social media data could also be portrayed, notably flickr[38] pictures. The use of social media data is valuable for practitioners and the participants because it allows the gathering in the same virtual space, the state of the place through stories (tacit knowledge which is laborious to gather through active interactions). Consulting pictures or comments from the social platform could help with the diagnosis phase of the project, where testimonies of the practices of the place are freely uploaded and discussed online at different times. These stories can help to understand the evolution of a place, identify practices and problems, or stimulate the imagination of participants.



Main functionalities:

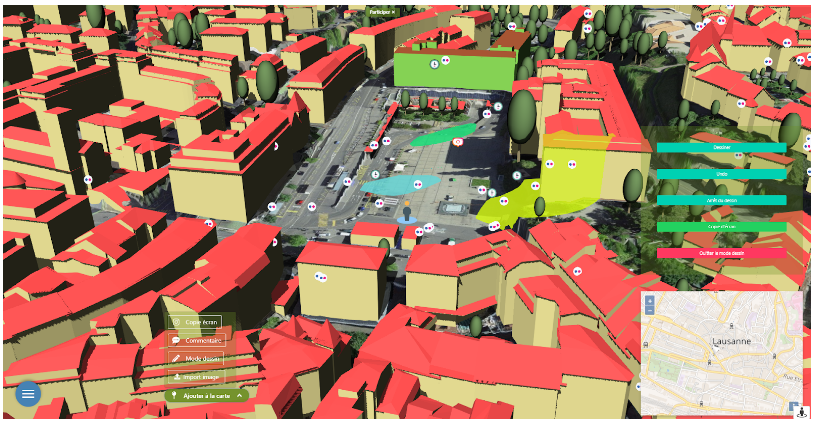
- All the functionalities of the previous platform
- Visualize social media data that is geo-referenced
- Add a picture from an idea pool in transparency on the 3D environment
- Take a screenshot of the view

Figure 4.4. *Screenshot of the second developed prototype and description of its main functionalities*

[38] https://www.flickr.com/

Prototype 3.

In this platform, the menu panel has been replaced by a button containing the categories. The goal was to have as much place as possible to visualize the 3D model. A few additional functionalities have been implemented, such as hand-drawing to give the opportunity to the participants to highlight elements in the virtual environment. Also, it was possible to switch to a Google StreetView visualization from the 2D map. The implementation of Google StreetView aims at supporting the participants' orientation. Photo-realistic representations help viewers to connect to some elements that are easily recognizable. Therefore, having this view available intends to help participants to better understand the place, without overloading the 3D environment. Once open, the StreetView container was connected to the camera of the virtual globe. This prototype was presented during the AGILE 2018 conference in Lund. The submitted short article accepted at the conference is provided in appendix A.



Main functionalities:

- All the functionalities of the previous platforms
- Sketch in 3D (hand-drawing)
- Survey with questions linked to the 3D environment
- Add StreetView container to compare with the 3D environment

Figure 4.5. *Screenshot of the third developed prototype and description of its main functionalities*

Prototype 4.

This platform results from several exchanges conducted with a Swiss municipality around the revision of its Master Plan (see Figure 3.2.). The prototype enabled participants to navigate within the virtual environment freely and to locate geo-markers in elements of the city. The markers were linked to information about the type of elements (buildings, parks, street furniture, etc.), an opinion (positive or negative), and the frequency of the visits (daily, monthly, etc.). Also, written comments and images could be added to the marker. The concept borrows some well-known mechanisms from PPGIS and emotional maps while extending their dimensionality. Geocoding and reverse geocoding were implemented in order to simplify orientation and navigation throughout the virtual space, in addition to the automatic collection of addresses from a location that minimizes typing errors. A demonstration of the platform can be seen following this link: https://www.youtube.com/watch?v=BE0SzAXf_bM.

Main functionalities:

- PPGIS/emotional map in 3D, users can pinpoint a location that they like/dislike with additional elements such as frequency of use, category, comment
- Geolocalization from an address bar and reverse geocoding from the marked localization

Figure 4.6. *Screenshot of the fourth developed prototype and description of its main functionalities*

Prototype 5.

This platform is based on the previous one with several implemented improvements in the front-end part. The required inputs from the participants/users were simplified to enhance the user experience. In addition, some adjectives were automatically recommended to the participants/users while being asked to fill in their opinions about the element.

<u>Main functionalities:</u>

- Visual improvement of the previous platform with an automatic suggestion of adjectives according to the opinion of the place
- Add simple steps to add a contribution

<u>Figure 4.7.</u> *Screenshot of the fifth developed prototype and description of its main functionalities*

Prototype 6.

The last platform initiated a transformation of the approach. Participants were still asked to record their opinion about (future) elements of the city, but, in this case, the participation was located in situ. The metaphors to manipulate the virtual globe were re-invented entirely, to have the sensors of the devices (GPS position, accelerometer, compass, orientation) manipulating the environment. Therefore, controls were now straightforward and simple without the direct interaction of the participants/users to rotate and pan the virtual globe. The participants/users simply have to look right or left, up or down with their device to change the position of the virtual camera. Furthermore, the participation was conducted by two buttons (👍 and 👎) that are constantly visible on the screen. Following this positive or negative feedback, a couple of optional steps are enabling the participants/users to complement their opinion further. Regarding the orientation, a 2D map was still present in the web application, hidden under a radar representation that informed the participants/users about their position relative to the objects under negotiation.

<u>Main functionalities:</u>

- Implementation of the guerilla e-participation
- Instant participation
- Manipulation of the virtual globe with the phone sensors

<u>Figure 4.8.</u> *Screenshot of the sixth developed prototype and description of its main functionalities*

4.3. Experiences With Institutions and Applied Projects Regarding the Prototypes

During this Ph.D. research, I have had the opportunity to be an observer as well as an actor in various participatory projects, thanks to the prototypes presented above. A few platforms were presented to city representatives of four cities (GV, LV, YV, GG). These experiences and the fruitful exchanges with the municipalities built an overview of the participatory approaches in real case scenarios, applied to diverse urban project contexts. Four platforms were released during this period. However, none of these prototypes convinced the authorities. The arguments put forward by the cities were: preference for 2D, fear that 3D will be used by the opposition of the project, bad timing, tools not adapted to the project (in terms of visualization, features, and technology), unappealing 3D representation (colors), not enough details. These past exchanges are described and developed hereafter:

Experience GV (December 2017, actor):

Context: This municipality intended to build two or three clusters of buildings on a hillside in the city center, in order to follow the densification guidelines enacted by the state. These buildings ought to house underground parking, which aims at freeing the city center from its parked cars. Building lots were not yet defined, but the authorities expected strong opposition from the public. A specific number of housing units had to be created, but their arrangements remained flexible: two larger and higher buildings, or three smaller buildings.

Proposal: In this context, a 3D platform was proposed where citizens could choose and submit a height proposal for the buildings. The total volume of the buildings was fixed and defined. Therefore, if a building is lowered, the neighboring building(s) are automatically higher. The mock-up of the platform is a vertical slider linked to each of the buildings to control the height (Figure 4.9).

Result: *The platform did not convince the city representatives.* With the volumes of the buildings being displayed within their surroundings, the authorities feared that some pictures of these volumes would be used by the project's opponents. Some angles of view (from below) can indeed be used by opposition groups to create a strong negative image of the project. In addition, a concern was raised about the use of the model by seniors. Concerns about the colors used for the texture of the buildings have also been raised. Furthermore, the authorities acknowledged that they would have needed this kind of 3D representation for one of their previous projects, which is still being delayed by the opposition at the moment.

Observations: We noticed a concern from the authorities about the adoption of new technologies and apprehension that images from the 3D environments could be used by opposition groups. The first representations of an urban project are crucial because they anchor the imaginary of the population that could make a quick opinion, which is difficult to change subsequently. However, these 3D visualizations do not have legal value and cannot be used in legal opposition steps.

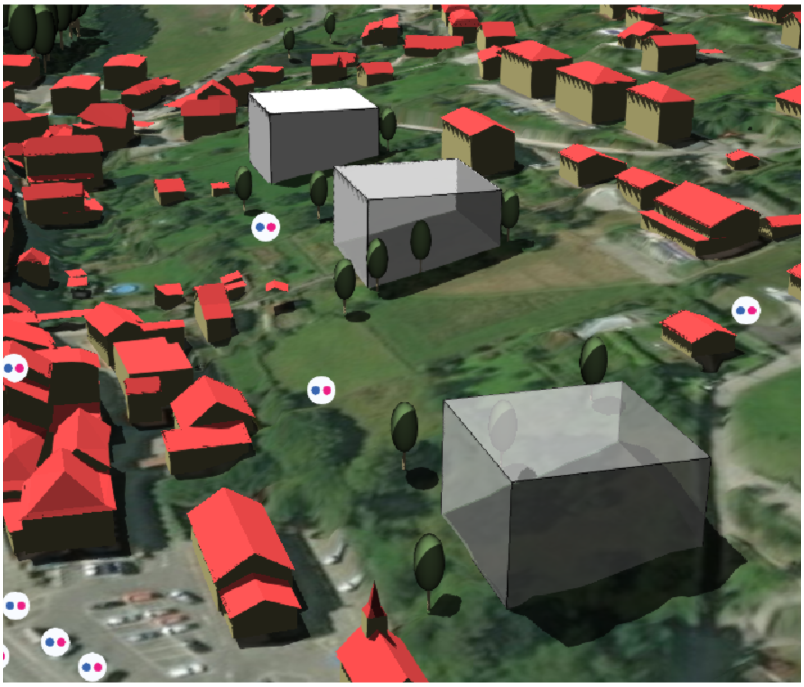


Figure 4.9. *Interactive visual of the platform that was presented to the city officials of GV. Three clusters were depicted at scale with different levels of transparency. A simulation of shadows depending on the time of the day and season was also available*

Experience LV (March-October 2018, actor):

This use case was presented at ECSA 2019 conference (see Appendix B and chapter 7)

Context: A Swiss city was planning to revise its Master Plan, and include the population in the process in order to increase the public acceptance and interest in the process. The Master Plan of a city aims to categorize areas to be built, enhanced, and conserved. This document is complex and addressed to experts; therefore, the municipality used a lighter version for the participatory process. The authorities' request was that the platform could identify areas of controversy, and compare citizens' insights with those of urban experts.

Proposal: A 3D participatory platform was suggested to collect and identify information about the perception of the district by the urban dwellers (Figure 4.11). A two-phase scenario for the utilization of the platform was created in order to support the users throughout their interaction with the platform. First, users had to pinpoint places where they usually go using the VGE, with the additional information being linked to the place: a category of the selected marker (street, square, park, building, tree, point of view), a visiting frequency (very often to very rarely). In the second step, the participants had to indicate elements of the city that they appreciated (or not). As in the first step, they had to categorize these locations with predefined categories and provide their preferences from "very appreciated" to "not appreciated at all" as well as the reasons for their choice (memory, attraction, animation, noise, etc.). In order to help the users to locate themselves in the VGE, an address bar and a 2D map were suggested on the platform.

Figure 4.10 illustrates the conceptualization and framing phase (taking the form of a workshop), which was organized with city officials and project leaders to design the prototype. The workshop happened through three steps: (1) presentation of the concept, along with an early version of the tool; (2) focus group work, where the participants had to imagine a potential usage of the tool and its functionality on a paper-sheet size A0 (where a small area of the municipality was printed); and (3) combining insights and presenting to the other groups.

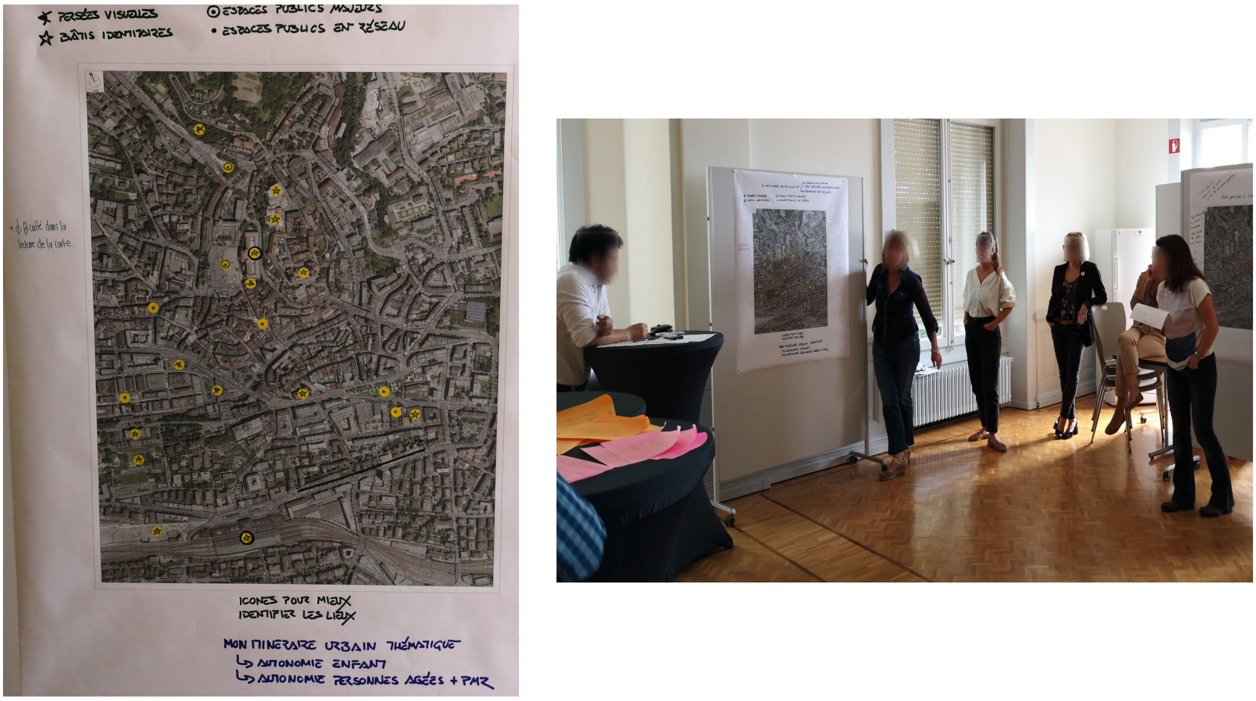
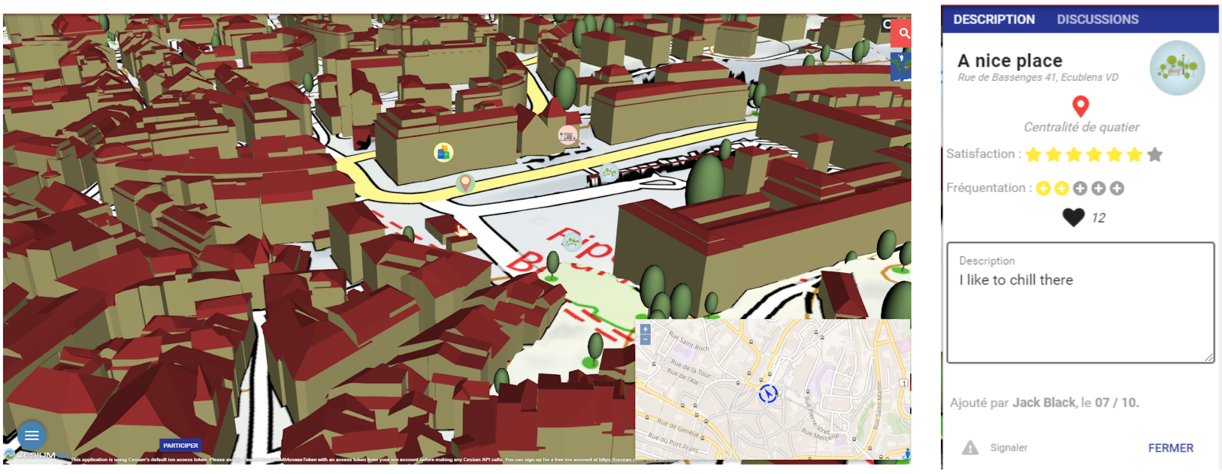


Figure 4.10. *Illustration of a brainstorming session that aims at designing a 3D participatory e-tool for the revision of the Master Plan of a Swiss city, conducted with the municipality officials and the project leaders*

Result: *After extensive discussions, the platform did not convince the city representatives*. The city demanded to abandon 3D visualizations and only use 2D maps. The municipality was concerned about using a 3D representation depicted in this platform that was still a prototype. The timeline and the development budget were limited. By adopting innovative tools, the city puts its image at risk to the population, if the project and the tool are successful the image of the city (and its officials, and politicians) will be positively fortified. However, if the outcome is negative, the same applies to the image of its representatives; thus, municipalities rarely accept taking such a risk. In addition, the authorities were surprisingly not interested in collecting the socio-demographic characteristics of the participants.



***<u>Figure 4.11</u>**. The prototype was presented at the LV municipality. The left image shows the virtual environment with some example markers. The left picture shows the information related to one marker*

<u>Observations:</u> The authorities' willingness to adopt 2D rather than 3D can be based on two assumptions. The first is about the suggestion of an abstract 3D representation that was not in line with the popular vision of photo-realistic 3D models put forward by CGI, video games, and architectural models. The second is related to spatial perception. A 2D representation of the space is more suited to portray large areas. The top view (2D maps) is facilitating spatial understanding due to its widespread use, its synthetic view, and adaptability to depict various spatial scales. The 3D visualizations seem to be more suited for smaller spatial scales (e.g., district or parcel). A solution to this second hypothesis could be a platform where large areas (city scale) are depicted in 2D and a transition to 3D that is offered once the user reaches smaller scales.

Experience YV (November 2018, actor):

<u>Context:</u> The objective of the municipality was to highlight the ongoing and future urban development projects. The city planned to transform several of its districts radically and would like to communicate to the population about its ongoing project with the right information. The projects to be displayed were very diverse and spread throughout the entire city with distinct scales, from the parcel to the district. Additionally, the municipality aimed to add to the projects, descriptions, and hyperlink texts.

<u>Proposition:</u> The prototype was made to integrate 3D models of the project (Figure 4.12). Information and images of the projects could be easily linked by depicting information boxes linked to the models. The goal was to inform the population (one-way communication), but no functionality from collecting feedback was promoted. Participants/users could navigate freely through the virtual environment and choose their points of view to visualize the project with its surroundings.

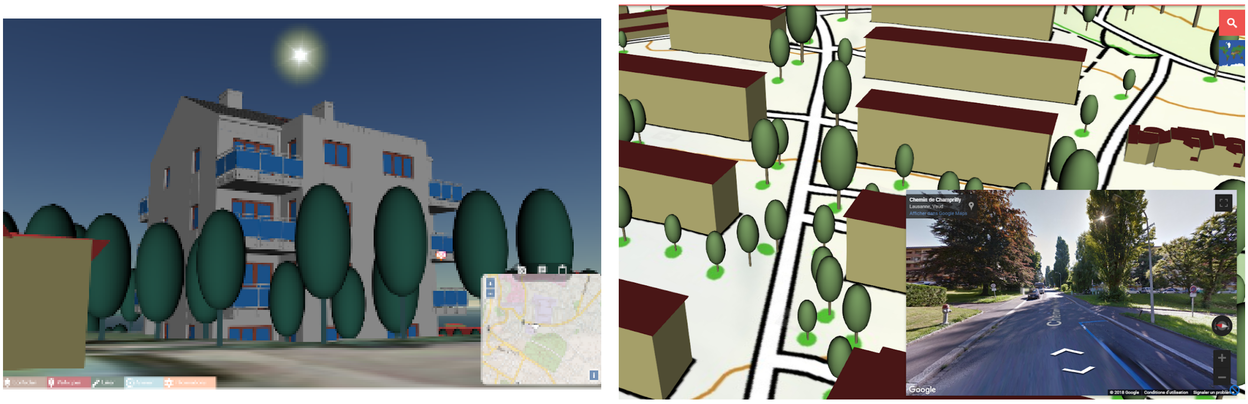


Figure 4.12. *The prototype was presented at the YV municipality. The left image shows the integration of an architectural design in the virtual environment. The right picture shows a visualization of the urban landscape and a street view of the same position on the ground*

Result: *No follow-up was given to the project due to the city's department reorganization*. The presence of the city's communication department strongly influenced the exchanges with the municipality. A non-technical solution was put forward, with a 2D artistic representation of the projects throughout the city (without realistic geolocation). Each presented project was detailed in an information box to communicate the appropriate information to citizens. It was mentioned that the platform could be used to visualize the urban projects in 3D but only from links displayed in the 2D artistic illustration. Concerns were raised about the complexity of navigation through the virtual globe.

Observations: During the presentation of the tool, the municipality expressed a great interest in the 3D. However, the aesthetics and simplicity of the representation appeared to be two central aspects of the possible adoption of this informative interactive tool.

Experience GG (June 2018, observer):
This use case is also discussed in chapter 7

Context: The general context of this project was the development of an industrial park (IP) not far from the Franco-Swiss border. The project consisted of the construction of a highway junction crossing agricultural fields that were located on the edge of residential villas. A solid opposition took hold of the project, going as far as the departure of half of the participants in the middle of a public session, where the authorities had presented the first version of the junction, notably with the help of a substantial 3D physical mock-up. Participants requested to cover the junction and according to them, they did not have the opportunity to influence the authorities' decisions because the mock-up presented an already final, inflexible result. More information about the project can be retrieved following this link: https://www.ge.ch/dossier/barreau-routier-montfleury (in French, last accessed the 08.07.2022).

Visualization: In a subsequent participatory session, the municipality reviewed its copy and redesigned a smaller physical mock-up with a semi-underground junction. In addition to this physical model, a 3D digital model was presented (Figure 4.13). It was created by an independent engineering office. The virtual environment displayed a realistic landscape of the built junction. A mobile camera enabled to move freely in the virtual scene; also, a mini animation simulating the view from a car passenger traveling at the junction was implemented. A few industrial buildings were represented by abstract volumes to mark the significant uncertainty about their construction. Participants did not have access to the controls that were carried out by an operator and a facilitator.

Figure 4.13. *The prototype was presented at the GG municipality. The left image shows the integration of an architectural design in the virtual environment. The left picture shows a visualization of the urban landscape and a street view of the same position on the ground*

Observations: Many participants crowded around this virtual environment. A strong enthusiasm could be observed, particularly because of the realistic effect of representation. Participants of all ages stayed several minutes in front of this 3D scene, pointing to the position of their house on the television in order to see the future junction from their digital window. This step allowed the participating citizens to project themselves into their daily future easily. The presence of this model has really been a benefit and eased the understanding of this project by the participants.

4.4. Link Between Papers, Methods, Prototypes, and Experiences

Paper	*Methods*	*In-house Prototypes*	*Experiences*
A	*Case studies: Media Coverage* *State-of-the-Art of the Scientific Literature* *Action-Research: Active Observations*		*GV, LV, YV, GG*
B	*State-of-the-Art of the Scientific Literature* *Action-Research: Active Observations*	*1, 2, & 3*	*GG*
C	*State-of-the-Art of the Scientific Literature* *Action-Research: Active Observations* *Action-Research: Interactions with Practitioners* *Framework Exploration*	*4 & 5*	*GV & LV*
D	*User Experiment (n=107)*	*3D in-house survey*	
E	*User Experiment (n=107)*	*3D in-house survey*	
F	*Usability Study (n=26)* *Semi-structured Interviews*	*6*	*GV & LV*

Table 4.1. *Summary table listing the different papers with their methods, prototypes, and experiences used*

Chapter

5. Paper A - Media Coverage of 3D Visual Tools Used in Urban Participatory Planning

List of abbreviations for the chapter:

ICT: Information and Communication Technologies
IA2P: International Association of Public Participation
CAD: Computer-Aided Design
LOD: Level of Detail
AR: Augmented Reality
VR: Virtual Reality
CGI: Computer-Generated Images

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5.1. Preface

The scientific literature review demonstrates a large range in the use of 3D visualizations *(or visual tools) in urban participatory planning. The collected studies describe different use cases and implementations than the number of studies. Therefore, use cases present in the scientific literature are highly specific, which is coherent with urban projects that are shaped based on their context. However, the practices of 3D visual tools are barely described from the practitioner's point of view. This knowledge foundation is nevertheless essential to better understand the practices of 3D urban participatory (e-)planning because practitioners are the actors that implement and design participatory practices. Through this chapter, I will collect several applied practices from media articles. These media articles will be analyzed and categorized according to technological parameters and contextual factors, which have been identified as significant in the scientific literature. With this outline of applied practices, I aim to identify how 3D visual tools are perceived by practitioners, and which are the determinant factors in their implementation.*

Publication and personal contributions

Chassin, T., Ingensand, J., and Joerin, F. (2022) *Media Coverage of 3D Visual Tools Used in Urban Participatory Planning*, International Journal of E-Planning Research (IJEPR) [**in revision**]

Personal contributions: formulation research goals and aims, development and design of methodology, data collection, analyze and synthesize study data, figures preparation, manuscript writing.

5.2. Abstract

The opportunities provided by adopting digitally generated visual tools in urban participatory planning are compelling. Perceived by academics, these tools promote interaction between authorities and citizens, and among citizens. The practices of 3D visual tools are often described from this academic perspective in urban projects that are limited and highly specific. However, little is known about the prospect of practitioners. This study investigates practices of 3D visual tools in applied urban projects. The applied projects were recovered from media coverage, which aspires to describe participatory projects and their adopted 3D tools, with a contextual and technical lens. The findings demonstrate that 3D visuals are mostly adopted for communication (i.e., realistic representation with limited interaction), in the later stage of the project (minor negotiation margins), at a small and medium urban scale. A better understanding of applied practices can help to introduce guidelines that support practitioners in designing approaches that benefit for the full potential of 3D visual tools

5.3. Introduction

The involvement of citizens, i.e., local experts, in urban development helps to tackle several issues specific to planning by conveying dwellers' judgments, feedback, or wisdom (Arnstein, 1969). However, engaging the population in complex topics that are pacing the steps of urban development is challenging (Alawadi & Dooling, 2016; Mostert, 2003), and the use of Information and Communication Technologies (ICT) in participatory approaches do not resolve all issues (Afzalan & Muller, 2018; Brown & Kyttä, 2018; Chassin et al., 2019). The authorities need to determine if the aspects under negotiation are accurately understood by the participants, in addition to guaranteeing that their provided feedback is meaningful and related to the urban issue. In this regard, visual communication is often favored, because of its efficiency in conveying information including better memorability and easier understanding of complex issues (Al-Kodmany, 1999; Christmann et al., 2020; Metze, 2020; Roque de Oliveira & Partidário, 2020). For instance, visual tools could promote the immersion of future users (i.e., affected inhabitants) in a soon-to-be-built urban project in order to understand its challenges. Otherwise, this understanding could be laborious, even impossible, due to the several complex aspects of urban design: lengthy timeline, large spatial scale, numerous design parameters, etc.

Since the late 80s, technological breakthroughs in the movie and video gaming industry provide digitally generated 3D visual tools that are increasingly detailed and realistic. This progress promotes, on the one hand, visualizations that are accurate and robust enough to portray urban projects (Chowdhury & Schnabel, 2020; Newell et al., 2021; White et al., 2021), and, on the other hand, a skilled population that is accustomed to experiencing these 3D representations. The recent maturity of these visualizations and their benefits for urban (and landscape) participatory planning has been acknowledged in the scientific literature (Al-Kodmany, 2002; Hayek et al., 2016; Lange, 2011), and numerous prototypes are implemented to engage the population (Alatalo et al., 2017; Chassin et al., 2018; Onyimbi et al., 2018; Velarde et al., 2017; Yu et al., 2020). These prototypes borrow several features that are well defined in the scientific literature such as Public Participatory Geographic Information System (Nummi, 2018; Sieber, 2006), geo-questionnaires (Haklay et al., 2018; Lafrance et al., 2019) or emotional maps (Pánek, 2016). The support of 3D representation in these features that are usually implemented in 2D shows a handful of improvements such as a better understanding of the complex aspects specific to projects that have a spatial extent (Voinov et al., 2018), the creation of a common language (Roque de Oliveira & Partidário, 2020), or the creation of a shared image of the project by all the participants (van der Land et al., 2013).

However, despite a growth in the use of digital technologies, notably with the development of Civic Technologies that aim to improve interactions between public institutions and the population, authorities seem to show hesitancy and concerns in adopting 3D visuals (Kitchin et al., 2021). This reluctance generates poor opportunities to develop applied practices of digitally generated 3D visual tools in an urban participatory context. As practitioners and scientists, the authors rarely observe projects that endorse these kinds of representations in their development. Even if adopted, authorities (and academics) seem to limit the use of 3D visual tools to a minimal setting, portrayed by examples having high specificity, and lack of scalability or reproducibility (e.g., Lafrance et al., 2019; Newell et al., 2021; Würstle et al., 2021; Yu et al., 2020). Therefore, in order to interpret the skepticism from the authorities and this lack of opportunities, this study aspires to identify characteristics, namely the contexts and the practices in which applied digitally generated 3D visuals are endorsed in urban participatory planning. The term “applied” is essential here, because the investigation of this study is conducted on real case projects that are originally mentioned in paper-based or digital-based media. This uncommon outlook has several benefits, such as the collection of projects influential enough to be mentioned in the media, a different perspective from the state-of-the-art studies that focus only on scientific projects, and the evaluation of projects that are related to the day-to-day work of urban practitioners, which have concerns that may be distant from academic perspectives.

In this media coverage (and additional information inquiry), this study aims to identify the most common characteristics of applied digitally generated 3D visual tools adopted by the authorities from January 2015 to December 2021. Only the urban projects that have a spatial impact on the territory will be considered, for instance, the implementation of new highways, the extension of buildings, or the conception of a new tram line. These characteristics will be explored in the light of two components: (1) the context in which the visuals are adopted; and (2) the technical aspects of the visuals. This classification promotes a state-of-the-art knowledge of the applied practices of digitally generated 3D visual tools in urban participatory planning. An understanding of the misuse, opportunities, and bias of these visualizations in urban planning could lead to creating a better visual design, broadening their use, and ultimately developing better cities. This paper first describes the features that were selected to categorize the different visuals. Then, the approach that was adopted to collect the media articles will be described. The following section illustrates the findings based on a descriptive interpretation as well as a feature association analysis. Finally, the findings will be discussed, starting with an accurate report of the current situation that will then support the development of prospects to enhance urban planning practices.

5.4. Compared Aspects and Typology

Participatory approaches have to be shaped according to specific aspects in order to be meaningful (Reed, 2008). The nature of these aspects is wide-ranging and fluctuates between contextual factors (such as economical, political, social, or linked to the urban project) and technical parameters (e.g., selected medium, visual representation, immersion, device); also, human factors play an active role in the design of the approach (according to the affinity or the experience of the team in charge of designing the approach) (Bouzguenda et al., 2020; Bryson et al., 2013; Hrivnák et al., 2021; Ling et al., 2009; Luciano et al., 2018; Sieber, 2006). Digitally generated 3D visual tools as vehicles of the interaction during participatory sessions reflect these various aspects. Three dimensions translate the design of these visuals: (1) *When?* that emphasizes the contextual factors; (2) *How?*, which illustrates the technical parameter; and (3) *What?* that bridges the two parameters together via the urban project itself and its depiction within the visual (Lovett et al., 2015). Each of these dimensions contributes to challenges that need to be addressed during the design of the visuals: users' idiosyncrasies, portrayals, contents, and technologies (Çöltekin et al., 2017).

This study aims to capture the previously mentioned aspects through media coverage of the use of 3D visuals in urban participatory projects. However, the vocabulary and the quality of the information mentioned in the media articles strongly varied according to the journal, public, writers, etc. Therefore, this section describes a precise typology based on the scientific literature, which characterizes the different aspects that will be used to classify the projects.

5.4.1. Contextual Factors

Contextual factors (*when?*) are crucial elements in the design of the participatory approach. According to their configuration, they could radically change the medium that is employed during a participatory session or limit the degree of freedom of the participants. With limited media coverage, reestablishing the entire set of contextual factors could be overwhelming, and not always relevant because of missing information or their high divergence within different cultural contexts (Zhang et al., 2019). Also, due to the diversity of contextual factors, the assessment of their impacts on digitally generated 3D visuals is challenging. Therefore, this article focuses on three project-dependent parameters that are easily recoverable in the media articles, and directly related to the 3D visuals: (1) project stage, (2) project scale, and (3) participation level.

5.4.1.1. The stage of the project

Any project (urban, non-urban, or from the industry) is subjected to a temporal evolution that regulates two elements: the definition of the project (i.e., how much the project is defined) and the latitudes to change the project (Chassin et al., 2019; Midler, 1998). This evolution is enclosed in stages that traditionally define the life cycle of urban projects: initiation, diagnosis, design (or plan), validation (which depends on the cultural context), implementation, and maintenance (adapted from Faliu, 2019; Wates, 2010). The role of the 3D visuals and their representation may vary according to the temporal stage, from a design tool using abstraction in the early stage of a project (enhancing creativity) to a communicative tool portrayed with a high level of realism (enhancing comprehension) (Hayek, 2011). Other descriptions of the life cycle of a project are also used in current planning practices, such as the urban planning pyramid that describes six phases: (1) Dialogue, understanding, commitment, and participation; (2) Visioning and creation of ideas; (3) Common understanding and goals; (4) Planning; (5) Building; (6) Maintenance (Oliveira e Costa et al., 2018). However, such granularity is difficult to label in the information recovered from media coverage. Therefore, the traditionally described stages were favored, whereas the initiation and the maintenance phase were excluded. The first is because the study focuses on projects launched through an authority's initiative, and the second is because of its lateness in the life cycle of an urban project; both do not provide participatory opportunities.

5.4.1.2. The scale of the project

Urban projects have a strong impact on the territory, which is materialized by a transformation of the urban landscape and an alteration of the practice modes of the place (Sebastien, 2016). Each project by its anchor on the spatial dimension will not have the same impact on the territory. These projects vary in terms of spatial scale (from the parcel to the agglomeration) and temporal scale (from several years to decades) (Arab, 2007). Three types of urban projects are selected in this study: (1) Architectural design, at a smaller scale, which is related to elements within a parcel or a plot such as buildings or parks; (2) Major Metropolitan, at a medium scale, is associated to a district and can aim at transforming a full neighborhood; (3) trans-urban, at a city scale, focuses on new strategies for the development of an entire city (Chassin et al., 2019). These scales are important for the 3D visuals and their portrayals because they result from different cognitive spaces (Montello, 1993), which affect the representation and the exploration of virtual environments (Kettunen et al., 2012).

5.4.1.3. The level of participation

The participation continuum (or ladder) that describes different levels at which citizens can affect decision-making, has been extensively investigated in the scientific literature since its introduction (Arnstein, 1969). This continuum was applied to different topics and has taken different shapes, such as for children's participation (Hart, 1992), for sustainable agriculture (Pretty, 1995), within the form of the wheel of participation empowerment (Davidson, 1998), or under a spectrum of public participation (IAP2, 2014). The last spectrum will be considered in this study. Each of these continuums illustrates the role of the citizens in decision-making under hierarchical levels, from lower rungs where the population is merely informed about the project or even manipulated, to higher rungs where the public holds the power of the final decision. The International Association of Public Participation's (IA2P) spectrum introduces five levels: inform, consult, involve, collaborate, and empower (IAP2, 2014). Advanced participatory tools, such as participatory mapping, have helped to anchor current approaches within the intermediate levels (Babelon et al., 2021). Based on observations, it seems that, unlike participatory mapping, 3D visual tools are adopted for communication and project promotion, located at the information level. Therefore, the entire continuum of public participation was considered to categorize the recovered projects. This spectrum will be altered by merging the three higher levels (involve, collaborate, empower) into the term "involve+". Two reasons are motivating this choice: (1) the scarce information mentioned in the press articles does not allow this granularity in the higher levels; and (2) the practices of digitally generated 3D visuals in participatory planning rarely seem to reach the higher rungs. Participatory levels will be only considered for a specific participatory session that uses the 3D visuals, and not for the entire approach.

5.4.2. Technical Parameters

Visual tools, such as digitally generated 3D visuals, seem valuable and even desirable for participatory planning. These straightforward representations of the environment can help to lower accessibility barriers and improve the inclusivity of the participatory processes; yet, their technical challenges and design process should not be overlooked (Metze, 2020; Roque de Oliveira & Partidário, 2020). Visual representations have a strong impact on how the population perceives a future project; therefore, they can facilitate the negotiations around aspects under discussion, or help the immersion. However, without technical understanding or specific guidelines, the built project can be significantly different from the one conveyed by the visual representations (Downes & Lange, 2015).

Certain parameters of visualization could be favored by the municipalities from their experiences, knowledge, and skills in dealing with these kinds of visuals. Any choice, intentional or not, tends to impact the perceived experience, validity, interactivity, and legibility of the visuals that are being shared with the population (Raaphorst et al., 2018). By investigating the technical parameters, this study aspires at identifying the redundancy of visual parameters and assessing the correlation of 3D visual specificities with external components, i.e., the contextual factors. This study will mainly focus on three technical parameters: (1) *format*, which questions the selected method to broadcast the 3D visual; (2) *control*, which identifies the degree of freedom provided to the participants for exploring the virtual environment; (3) *portrayal*, which recovers the detail of the portrayed virtual models, and their aesthetic representations.

5.4.2.1. The format

Digitally generated 3D visual tools are broadcast during urban participatory sessions in various formats or mediums. A selected medium result from technological aspects (analog vs. digital) and type aspects (board, poster, projector screen, etc.) (Raaphorst et al., 2018). Different 3D mediums are adopted more frequently than others, for instance, Computer-Aided Design (CAD) drawings rendered in 3D (Wanarat & Nuanwan, 2013), videos (Manyoky et al., 2015; Velarde et al., 2017), or immersive virtual reality (Chowdhury & Schnabel, 2020). These mediums change how the participants experience the future urban project, and based on this experience, participants will refine their opinions or contributions to the participatory approach. Therefore, the selection of a format should be mindfully considered by institutions. For this parameter, a specific typology is not defined, the format employed in the articles will simply be reported.

5.4.2.2. The controls

The freedom in terms of controls, which allows participants to manipulate or explore a 3D visual actively affects the participants' behavior (Chassin, Ingensand, et al., 2021). Therefore, the degree of freedom adopted by the authorities should be carefully selected. It has been demonstrated that static vs. interactive or immersive vs. non-immersive representations alter users' performance and judgment (Dong, Yang, et al., 2020; Juřík et al., 2020). However, being confronted by the interactive inequities introduced by 3D visual tools (Schroth et al., 2011; van der Land et al., 2013), the institutions face a dilemma about the extent of freedom that should be implemented within the 3D visuals. The interaction functionalities that are implemented in the 3D tools will be recovered from the media articles, from non-interaction through navigation and consultation of information, to the design of public places.

5.4.2.3. The portrayal

The portrayal of the 3D visuals, or their level of realism, greatly affects the cognition of the participants. On the one hand, realistic depictions help the participants' orientation and encourage emotional bonding with the project. On the other hand, abstract representations ease the cognitive load conveyed by the visual and tend to focus the participants' attention on the subject under discussion (Hayek, 2011). Two components constitute the parameter of portrayal: the Level of Detail (LOD) and the style (i.e., representation).

The LOD describes how precise a 3D model is. The definition that classifies LOD into nine levels was adopted, from a simple 3D block to a building that has its interior furniture modeled (Biljecki et al., 2014). This granularity has been aggregated into four main categories to simplify the identification of the detailed levels, which are sometimes hard to differentiate in the recovered 3D visuals: *low* (LOD 0, 1, and 2) that corresponds to simple models with straight wall extrusion, simple roof shape and no vegetation; *medium* (LOD 3, 4, and 5), which may contain a simple balcony, roof structures, and vegetation areas; *high* (LOD 6, 7, and 8) that adds precise vegetation, window opening, textures, and finer structural elements; and *very high* (LOD 9), which is the most accurate model in terms of detail. The role of vegetation is an important factor in the portrayal of urban projects, and occasionally vegetation elements were more detailed than the project representation. In this specific case, the LOD from the project would prevail.

Regarding the style or the visual representation of the project, three categories were adopted: schematic, realistic, and atmospheric (Raaphorst et al., 2018). The schematic style, similar to abstract representations, aims at easing the legibility of the scene. The realistic (or photo-realistic) representation aspires to mimic reality. The atmospheric style, also close to reality, takes advantage of digital filters to smooth the representation and seeks to produce an emotional response.

5.5. Research Approach: Media Coverage

The research approach employed in this study (media coverage) mimics the process described for systematic reviews. The prospect of these two research methods is similar: collecting all the mentions of a subject under investigation. Typical systematic reviews are articulated around five steps: (1) definition of a strategy to collect the related studies; (2) selection of the relevant studies (first filter); (3) evaluation of the quality of the recovered studies (second filter); (4) labeling of the information present in the studies, (5) description of the data (Kitchenham, 2014). However, adopting a systematic review approach for collecting media articles that mention the use of digital-generated 3D visuals applied to urban participatory planning is challenging. First, the vocabulary mobilized by these domains is not yet defined, which leads to a profusion of words related to the topic, and the development of different corpus between experts. Second, the terminology employed to describe urban participatory planning and 3D visuals is not specific, which implies that a wide range of domains is also using the same terminology. Third, media communication aims to reach a broad, non-expert population, hence, the stories found in the media articles are often abridged and oversimplified. Fourth, the worldwide number of media channels is overwhelming, which makes the identification of relevant articles difficult. Therefore, the procedure for the systematic reviews was adjusted, and the similar approach implemented for the media coverage in this study is presented in Figure 5.1.

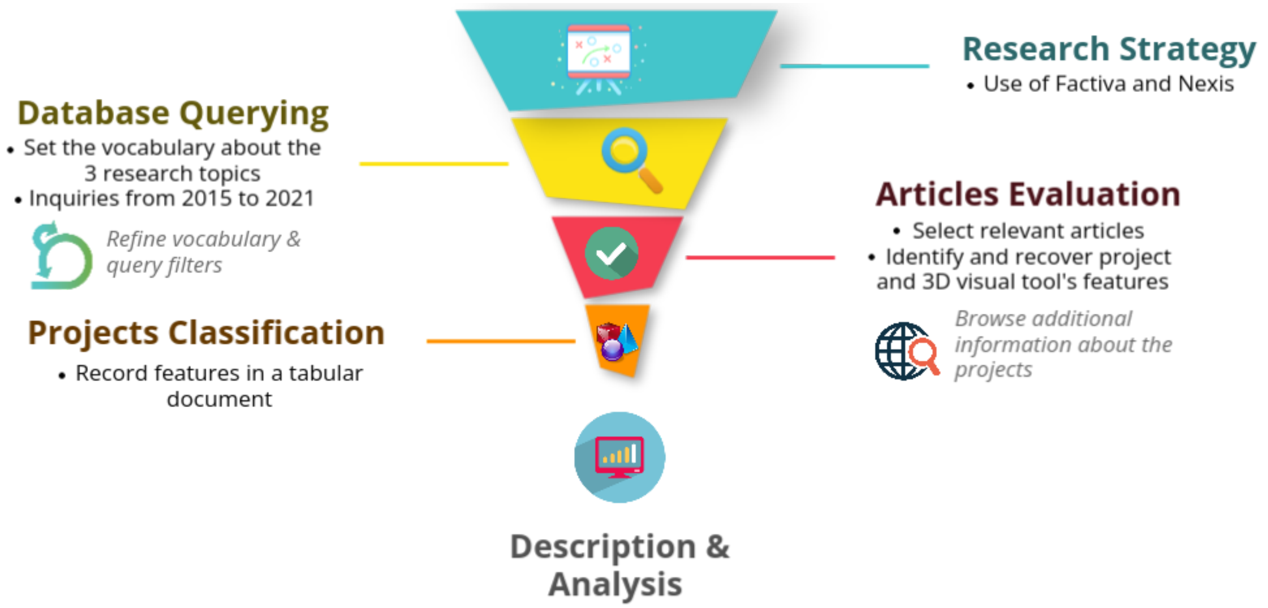

Figure 5.1. *Description of the steps executed in the media coverage*

5.5.1. Research Strategy: Media Aggregator

Two media aggregators (or databases) were selected to identify and collect the media articles related to digitally generated 3D visuals applied to urban participatory planning, namely Factiva (dowjones.com/professional/factiva/) and Nexis (lexisnexis.com/en-us/home.page). The research scope ranged from 2015 to 2021. These two platforms index numerous articles that are published worldwide, which facilitates the exploration of media articles by reducing the number of sources to query without limiting the reach of the data collection. Furthermore, besides having similarities to the approach employed to collect scientific articles with tools such as Scopus (scopus.com/home.uri) or Web of Science (webofscience.com/wos/woscc/basic-search), these tools provide advanced functionalities, which allow more flexibility in the design of the query and the opportunity to conduct progressive filtering methods. However, the adoption of meta-tools implies some challenges: (1) media channels from several domains are indexed, which leads to severe noise in the data collection; and (2) the limited number of media channels that are indexed (e.g., local media are not recorded).

5.5.2. Database Querying

Before querying the media aggregators, a vocabulary was established, which encompasses the three domains of the media coverage: (1) 3D visuals, (2) urban planning, and (3) citizen involvement. Numerous scientific systematic reviews have already been conducted on these domains (e.g., Eilola et al., 2021; Falco & Kleinhans, 2018; Metze, 2020). Therefore, the vocabulary employed in these studies was first adopted, with terms such as (1) 3D, visualization, virtual globe, 3D model, digital twin for the 3D visuals; (2) planning, building, design, city for the urban planning thematic; and (3) involvement, engagement, collaboration, public, citizens for the public participation. Queries were challenging to design, and the number of results was often overwhelming and did not perfectly fit with the target. Therefore, the vocabulary of the queries was gradually transformed. The results were also cut down by applying increasingly complex filters. The queries that generated a working number of articles are detailed in the *appendix C* section, along with their filter setup.

5.5.3. Articles Evaluation: Selection and Identification

The media article titles returned by the queries were manually scanned. The most relevant articles were short-listed and saved. The exported articles were scrutinized in order to identify pertinent aspects of the project, the participatory setup, or the 3D visuals. This step correlates to the *quality assessment* of the systematic review, where the authors determine if all crucial elements for the following analysis are suggested within the articles. If some of these elements were missing (such as a picture of the 3D visual), the lacking data was recovered by browsing information about the urban project on the city website. However, whenever the lacking component was not identified during this exploratory step, the article was dismissed (Figure 5.1). Furthermore, the articles were only kept if the use of digitally generated 3D visuals was mentioned in urban projects that have a spatial impact (such as new constructions, new layouts for a park, or extensions of existing structures). The projects related to the redesign of interior spaces were not taken into account. Moreover, the 3D visuals had to be broadcast to a group of people (public, private, officials, etc.).

5.5.4. Projects Classification

At this step, all additional information about the project, the participatory setup, and the 3D visuals were already collected. The typology described in Section 5.3 was used to categorize the articles and projects. The data was gathered in a tabular file, which was then transformed into a CSV file in order to facilitate the comparison of the articles and carry out the analysis. This data is available in *appendix C*.

5.5.5. Description and Analysis

Python programming language (python.org) was used to analyze and compare the projects' features. Then, Plotly (plotly.com), a graphic library, was adopted to create the different plots. A descriptive comparison was first conducted, then Sankey diagrams were designed to link the different parameters of the urban projects (context) to the ones of the 3D visual tools (technical). Last, statistical tests (Chi-Squares and Fisher Exact Test) were estimated using R (r-project.org). This different programming method was used because the implementation of the Fisher's exact test in Python does not allow using a contingency table greater than 2x2. Chi-Squares were used if more than 80% of the values of the estimated contingency table were superior to 5 (Kim, 2017).

5.5.6. Limits of the Media Coverage, From the Scope to the Wow-Effect

The media coverage approach has numerous benefits, which notably are: the opportunity to reach a worldwide range of media articles, and the collection of projects that are applied and adopted by institutions. However, this approach leads to bias that should be considered (Barranco & Wisler, 1999; Earl et al., 2004; McCarthy et al., 1996). First, as mentioned before, the databases list a limited number of stories, which are mainly published on a national or regional scale. However, urban projects are anchored on a local scale and participatory sessions are applied even on a smaller scale, which is inconsistent with the scope of the media aggregators. For example, a city of a couple of thousand inhabitants that undertakes the renewal of its downtown will not, most of the time, attract the attention of other (larger) cities located hundreds of kilometers away. Therefore, the number of stories mentioning the use of digital visuals in urban participatory planning is expected to be low and incomplete. Second, Factiva and Nexis aggregate regional and national-based media, therefore, if the story of a local participatory session is published in these media, it often has unusual components (wow-effect). Indeed, these components are either related to the technology (Digital Twin, AR, etc.) or singular contextual factors (such as a strong opposition, the engagement of children, or a strong level of involvement). Therefore, the collected stories are expected to adopt a state-of-the-art approach, i.e., not fully representative of typical urban participatory planning projects. Regarding opposition groups, politicizing the debate by mobilizing the media attention is one of their favored instruments, thus it is also expected to come across several of these cases.

5.6. Results

The results presented in this section are based on 132 worldwide media articles published between January 1st, 2015, and December 31th, 2021. The queries that were conducted on Nexis and Factiva provided more than 30 000 articles that were reduced to 1 300, following the methods mentioned in the previous section. Of these 1 300 short-listed articles, 132 articles fulfilled the required conditions. Surprisingly, 75% of the articles were published in French and 25% in English, over 15 different countries. Most of the articles were released in France, Canada, the United States, the United Kingdom, and Australia. Notwithstanding, every continent was represented in this dataset (2 from Africa and 2 from Asia). Each of these articles' pictures one urban project using 3D visuals at a specific time; the life cycle of an urban project can see several consecutive 3D representations. Having two articles mentioning the same project at two specific times were rarely encountered; in this atypical situation, the first mention was always kept. The description of the articles through the related parameters is displayed in the table attached within *appendix C*, alongside the metadata. In this result section, the descriptive results of the articles will be shown first, then, in a second subsection, the relationship between the aspects of the urban project, participatory setup, and 3D visuals will be investigated.

5.6.1. From Articles to the Evaluation of the 3D Visual: A Practical Example

To portray the evaluation of the contextual factors and technical parameters, two examples recovered from the press articles will be extensively discussed in this subsection. The objective is to demonstrate the method and assessment as accurately as possible to enhance the reproducibility of this study.

5.6.1.1. Virtual Transect Walk in Rennes, France

[*This article is located in line 11 of the tabular document provided in the appendix section.*]

The story published in 2016 mentions the involvement of the citizens of Rennes, France through 14 transect walks that aim at helping the population to better appreciate their city and to be able to foresee its future in 2030. Following this broad presentation, the article reports that these transect walks can be conducted in groups during a guided tour, alone, with the help of a guidebook, or virtually thanks to the website *rennes2030* developed by 3DEXPERIENCity (3ds.com). The web application enables the users to record geo-referenced comments or answer a survey freely. From this document, the identified contextual factors were: (1) the transect walks are spread over the entire city and the name of Rennes 2030 indicates a trans-urban project, (2) the project Rennes 2030 is in its early stage and aims at collecting initial feedback from the population, which demonstrates a diagnosis stage, and (3) these interactive transect walks aspire to collect feedback and insights from the population, which suggests a consultation approach.

The online platform *rennes2030* was then investigated. The web app displays a "*Digital Twin*" (the term employed by the provider of the city model) of the city of Rennes, where the user can navigate with a birds-eye-view through the model at a Level of Detail 3. The shapes of the buildings are not too detailed, but a realistic texture from aerial images has been draped on these models. No fog or post-lightning processing has been added. Thus, the style is realistic.

5.6.1.2. Immersion in the New Road Between Troon and Loans, United Kingdom

[*This second dissected example is positioned in line 116 on the provided document.*]

The story was published in 2021 for the city of Troon, United Kingdom. The article presents the design of a new road in consultation with the population. The group that leads the project won a prize for their valuable usage of technology. A 3D video of the road was created to help the residents to understand the project during its second phase better. Besides the video, the 3D model could be visualized from a pedestrian or cyclist perspective with a head-mounted device. Then, the article emphasizes the crucial role of social media and communication. While consulting the website of the project on Sweco (sweco.co.uk/projects/loans-to-troon), it appears that the 3D model was created to ease the conveyance of "ideas and ambitions of the project". There was no mention of the use of the video or 3D model in a consultative setup. The project of a road has a large scale but is specific to one structure, therefore, this road project can be defined as a major metropolitan project. This video was created after the first phase of consultation and has been conducted during the design phase of the project. Despite designing the project in consultation with the public, there is no tangible evidence that the video and the project were used in a consultation setting with the population, thus, the process was defined as passive.

Regarding the 3D model recovered from the project website, the style is realistic, and no interaction is provided within the video and presumably within the immersive VR depiction. The Level of Detail is systematic with details such as light poles, and trees with their leaves; however, the sides of the road (sidewalk and grass) seem to be less detailed. Therefore, the Level of Detail was evaluated at 7. The additional buildings were designed schematically (LOD 1). Since they were not part of this project, the authors did not consider them.

5.6.2. Descriptive Results

5.6.2.1. Contextual factors

To evaluate the preferred contextual factors in which 3D visuals are adopted in urban participatory planning by the authorities, the frequency of the aspects identified in the press articles was analyzed. This evaluation demonstrates the contextual background that is prone to digitally generated 3D visuals (along with their setting). Four parameters were assessed: (A.) stage of the project; (B.) project scale; (C.) level of participation; and (D.) the goal of the visual, which indicates the objectives of the authorities when endorsing and sharing the 3D visual tools (see Figure 5.2).

Digitally generated 3D visuals appear to be mostly adopted in the design phase of the urban project (49%) (Figure 5.2.A). This phase is highlighted by a shift in the role of the 3D visuals that translate from a design tool to a communicative tool. The emphasis on this communicative property of the 3D visuals is illustrated by their goals, which are mainly to inform and immerse the participants or promote the project (for 68% of the total goals) (Figure 5.2.D). Moreover, presenting the results of previous interactive sessions or participatory steps adds 8% to the communicative property of the 3D visuals.

The visuals are adopted in a design or consultative setup for only 23% of all the goals identified (Figure 5.2.D). This low interactivity between the participants and the 3D visuals is highlighted by the level of participation, which remains in the lower rungs, namely passive (60%) and consultative (26%) (Figure 5.2.C). These two levels imply that participants are mostly receivers of information, but may provide feedback that is regarded as suggestive and not as a contribution to the negotiation area. In the few examples of interactive participation, the authorities tend to endorse visuals that are shared through serious games (representing around 50%). Therefore, it seems that 3D visuals are mostly used to promote and sell an urban project to the population rather than engaging them in the design of the same project.

The last aspect to be mentioned is the project scale, which shows that digitally generated 3D visuals are adopted in smaller urban project scales, namely the major metropolitan (55%) and the architectural design (28%) (Figure 5.2.B). Less present trans-urban projects are largely composed of solutions about “Digital Twin” technologies (around 70%) that aim, according to the providers, to create a digital copy of a city in order to enhance the efficacy of some processes, such as simulation, citizen involvement or urban development.

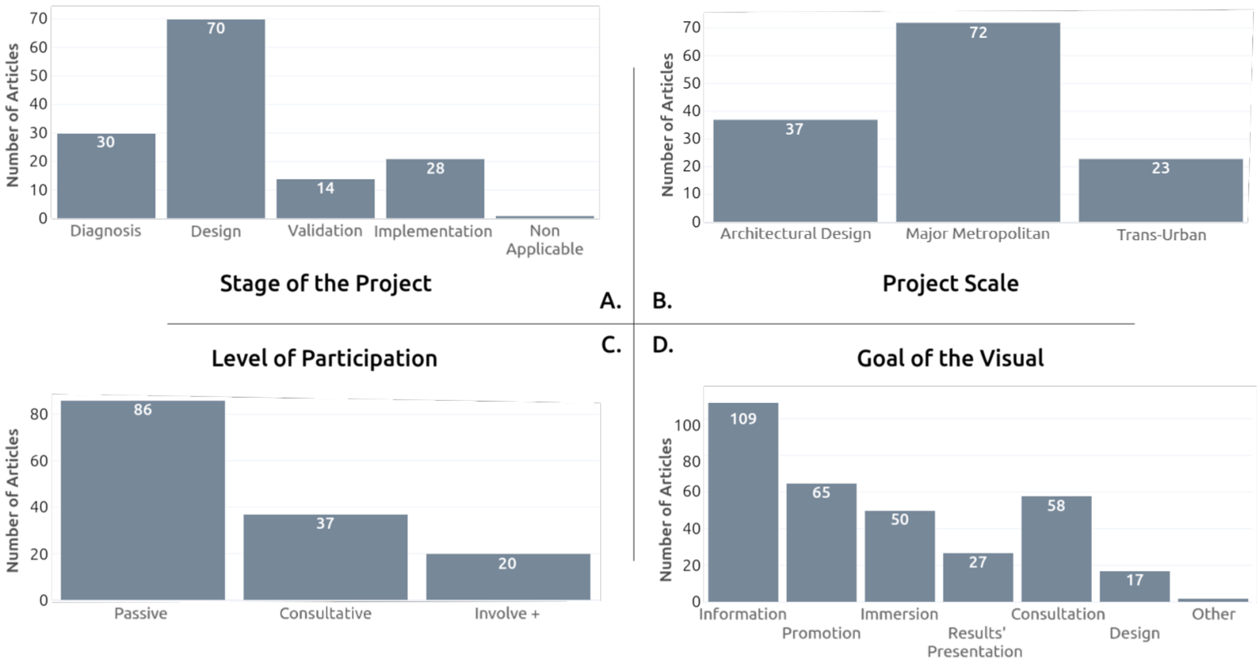

***Figure 5.2**. Distribution of the articles and 3D visuals according to the contextual factors*

5.6.2.2. Technical parameters

To investigate the technical parameters of the 3D visuals that are typically adopted in real urban projects, the prevalence of the visuals' characteristics regarding four aspects was assessed: (A.) the broadcasting technology of the visuals; (B.) the freedom that the participant has in controlling the 3D visuals; (C.) their Level of Detail; and (D.) their visual representation (see Figure 5.3).

The authorities mainly adopt photo-montage or non-immersive VR to create and share the 3D visuals (Figure 5.3.A). Other technologies such as immersive VR (with a cardboard or a VR headset), augmented reality (AR), or mixed reality are also used, but to a lesser extent (around 20%), which is notable even though the mentioned "wow-effect" bias should be taken into account. Moreover, the visuals are mostly produced with limited interaction. The results show that 57% of the visuals do not provide any type of manipulation (Figure 5.3.B), which reduces the opportunities to provide feedback from the participants. The preferred formats are static images or video clips that correspond to a practice, which is limited to communication purposes (as seen in the previous section). Basic exploration is also implemented such as navigation (27%), but it is often restricted to a pre-recorded setup of localizations. This constrained set of perspectives is, on the one hand, convenient for the creator of the model, who does not need to design the whole area, but can limit his work to the visible spaces, hence limiting the time and cost required to create the 3D visual. On the other hand, the limited mobility is also favorable for the authorities that can impose the points of view through which the digital future project will be explored by participants. Surprisingly, only rare articles (11%) mention the use of visuals as a medium to gather digital contributions from the participants (Figure 5.3.B).

The appearance of the 3D visuals shows a preponderance of realism with 58% of the models having at least a high level of detail (Figure 5.3.C) and 54% a realistic representation (Figure 5.3.D). This hyper-realistic representation of the future urban project is in line with current technological advances in 3D that are seen in Computer-Generated Images (CGI) and video games. However, this representation crystallizes the image of the project, which therefore offers no prospects to integrate negotiated elements provided by interactive sessions with the population. Moreover, this realism popularity does not appear to be in line with projects that are conducted during their design phase (Figure 5.2.A). During this phase, digitally generated 3D visual tools should help to gradually build a legitimate image of the project, from an abstract to a more realistic representation of the project. Therefore, this massive adoption of realistic representation demonstrates the use of the 3D visuals at the end of the design phase, i.e., in the late stage of the project.

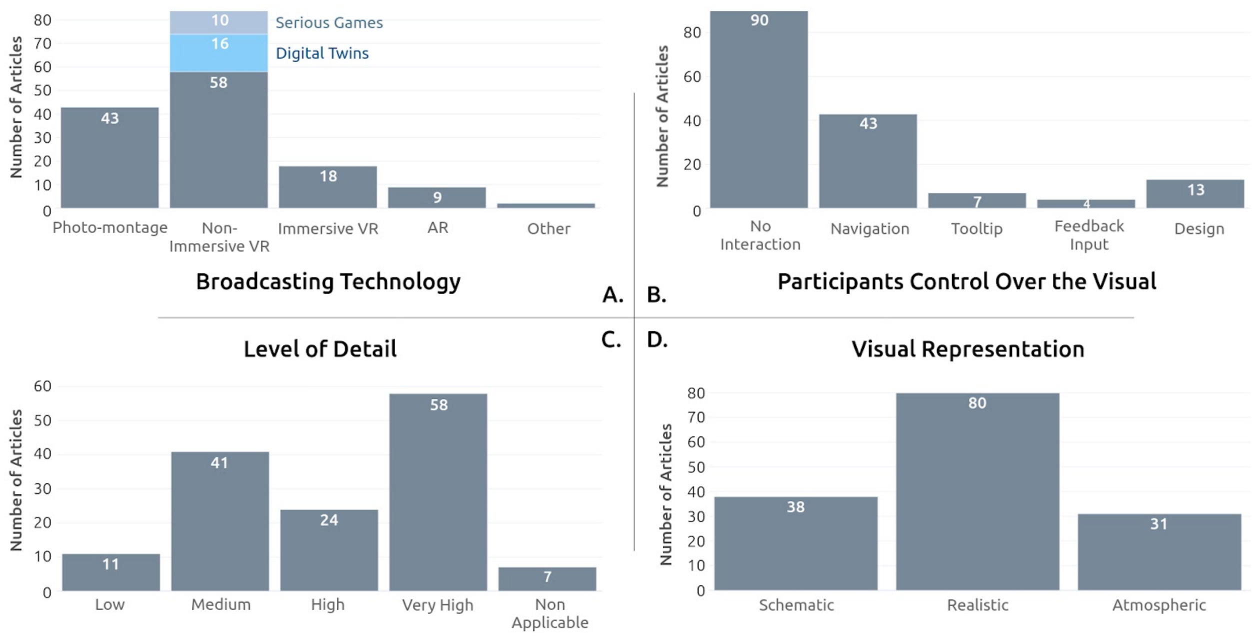

Figure 5.3. *Distribution of the articles and 3D visuals according to the technical parameters*

5.6.2.3. Temporal evolution

To investigate the reach of digitally generated 3D visuals in urban participatory planning, the articles were characterized by year of publication (Figure 5.4). This distribution aims at assessing the penetration of the 3D visuals per year, but also at comparing their use online vs. on-site. An interesting aspect of depicting the recurrence of 3D visuals per year is to evaluate the impact of the COVID-19 pandemic on their adoption.

No significant trends were observed on these graphs. The year 2020 is marked by a dramatic drop in the number of projects adopting 3D visuals (Figure 5.4.A). This drop was expected with nearly a complete stop of urban participatory planning projects due to the COVID-19 pandemic. The year 2021 shows a return to a more regular situation.

Regarding the ratio online/on-site, there is evidence to suggest a moderate increase in online projects since 2017 (Figure 5.4.B). However, the pandemic years (2020 and 2021) do not demonstrate a revision of this trend. The authors would have expected an adaptation of the participatory practices induced by the duration of the sanitary measures that were exceptionally long. It seems that the authorities aspire to keep adopting traditional in-person participatory approaches since their improvised experiments with online tools were unsuccessful during the pandemic.

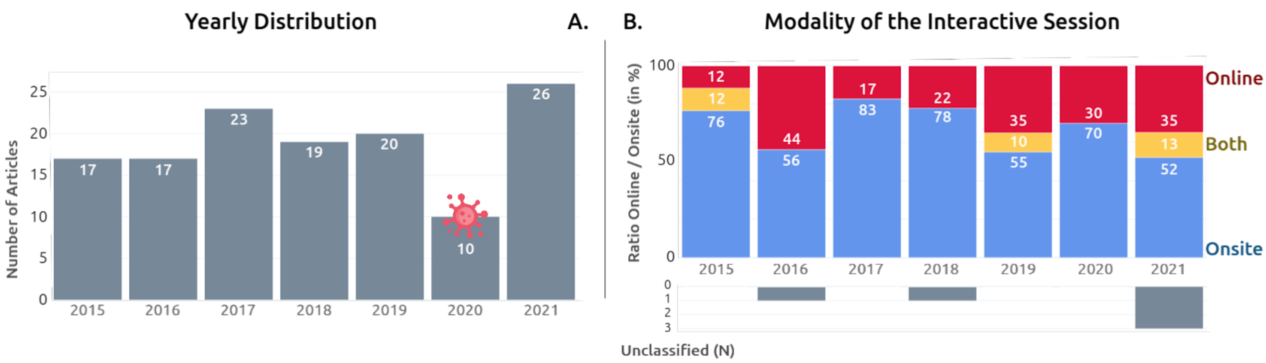

Figure 5.4. *Yearly distribution of the press articles*

5.6.3. Association of the Parameters

The frequency of each contextual factor or technical parameter that is described in the previous section portrays the structure of the interactive sessions using 3D visuals, which are mostly adopted in real case scenarios. This overall picture is valuable to understand better how 3D visuals are currently adopted in urban design projects. However, the connection between technical and contextual factors is not mentioned within these raw descriptive results. Therefore, the combined frequency of the technical and the contextual factors were investigated to describe their connection better. The next figures (Figure 5.5, Figure 5.6, and Figure 5.7) show a representation of this aspect using Sankey diagrams. Furthermore, a Chi-Squares or a Fisher Exact Test value was calculated for each of the associated parameters in order to assess their dependence.

5.6.3.1. Project stage vs. technical parameters

To investigate which technical parameters tend to be adopted depending on the project stage, a Sankey diagram was created to visualize the intensity of their connection (Figure 5.5). The results suggest that the early stage of the urban project, i.e., diagnosis, adopts mainly non-immersive VR which offers more flexibility to the practitioners in terms of participatory tasks, interactivity, and representation that provides a less conclusive version of the portrayed project. Contrastingly, static photo-montages are rarely employed (typically used in later stages). The adoption of explorative methods is also shown in the parameter “Level of Detail”, which demonstrates a high diversity in distribution, including non-categorized level (NA), i.e., 3D models created over Minecraft (minecraft.net). Moreover, no post-processed visuals (atmospheric style) are in use at this stage, limiting the crystallization of the project representation in the participant's collective imagination.

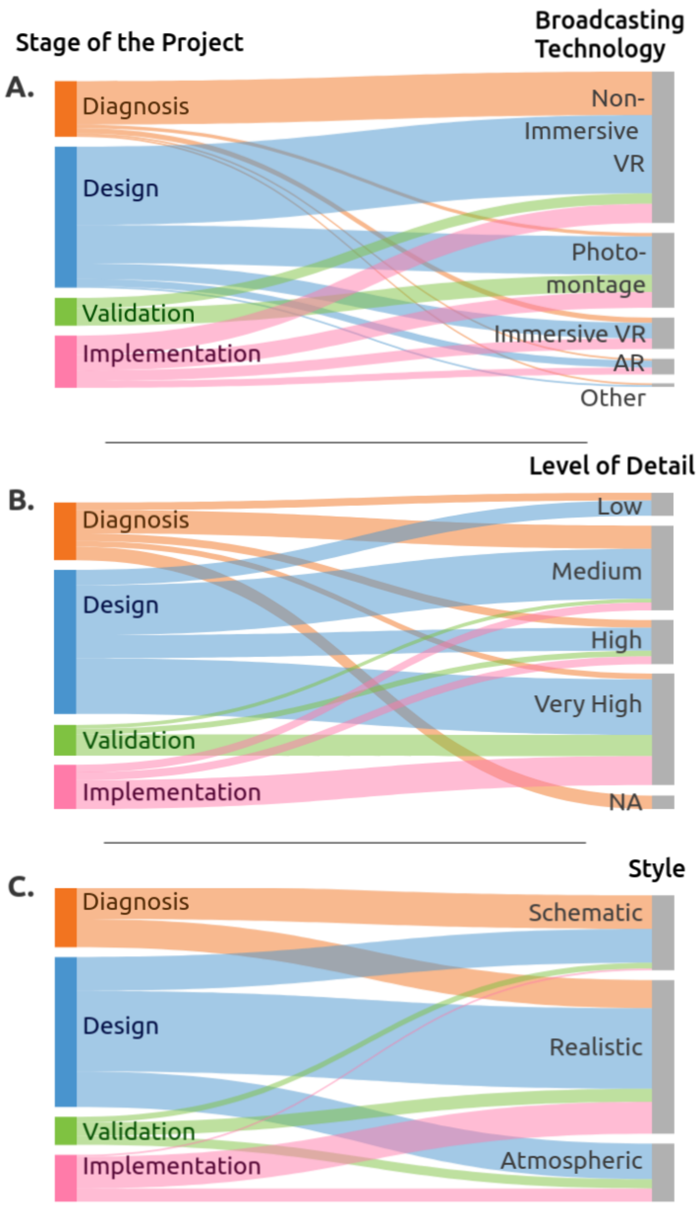

Figure 5.5. *Diagrams showing the intensity of the connection between the stage of the project and the technical parameters. A, B, and C represent this information in the shape of a Sankey diagram which links the nodes of each parameter together. On the right of each figure, the resulting p-value of the assessed Fisher Exact Test is shown*

The design phase is more equally distributed, which is not surprising because this stage is situated between the early and the late stage of the project, therefore, it uses different representations with diverse objectives. However, this stage appears to enclose most of the visuals adopting photo-montage. A lower Level of Detail (low and medium) seem to be constituted principally for the design stage, but extensive use of high and very high Level of Detail was also observed. This transitive stage adopts each of the styling representations, which is coherent with the range of applications of the design phase. If the urban project is in the early stage, thus, near the diagnosis phase, the abstract representation may be used, and on the contrary, during the late stage of the project, the realistic representation may be more adopted.

During the validation and implementation phase, the timeline of the urban project is greatly reduced and becomes more tangible. The objectives of the visuals are, in this timeframe, to settle the project in the collective imagination of the communities/participants. Therefore, more immersion and realism are preferred to engage the population within the future project, notably through the use of immersive technologies in VR or AR, a higher Level of Detail, and a style depicting realistic 3D scenes.

A Fisher Exact Test value was evaluated to investigate the independence of these two parameters (project stage vs. technical parameters). The tests demonstrate that all the technical parameters (broadcasting technologies, levels of detail, and style) are dependent on the stage of the project and that the study's findings do not come from a random distribution. For this statistical test, the value "other" from the broadcasting technologies and "NA" from the Level of Detail was not considered.

5.6.3.2. Project scale vs. technical parameters

Then, the same technical parameters were investigated with another contextual factor: the project scale. The findings are depicted in Figure 5.6. Smaller scales, i.e., architectural design projects seem to be related to more realism within the visuals with a strong proportion of the very high Level of Detail and post-processed representations (atmospheric style). At this scale, the concerned space by the urban project is limited, which leads to moderate 3D scenes that are faster and less restrictive to design, which encourages more complexity (highlighted by the high and very high Level of Detail). Also, a small-scale model consumes less computational power to render properly. Moreover, at this scale, all broadcasting technologies are employed, and an important connection is highlighted for the photo-montage. The use of photo-montage is not surprising considering the small area to visualize, which is easier to portray than a large environment.

The medium scale urban projects, namely major metropolitan, are portrayed by various kinds of broadcasting technologies adopting diverse styles and levels of detail. Being the most frequent scale mentioned in the articles, a larger diversity is identified in its practice and representation, for instance in significantly adopting augmented reality, photo-montage, immersive virtual reality, and non-immersive virtual reality. Furthermore, as the architectural projects, the major metropolitan projects lean toward more realism with a preponderance for a very high Level of Detail. A medium Level of Detail was also observed, which can be explained by the variation of scale encountered in these kinds of projects, from revitalizing the downtown of a city to planning a highway through an island.

The trans-urban projects mobilize the largest scale; therefore, their portrayal is challenging due to the number of elements in the model. For this scale, two broadcasting technologies are only observed with an overwhelming majority for non-immersive VR. The Level of Detail is mainly low and medium with a few exceptions. The connection between trans-urban project vs. atmospheric representation was absent; the post-processing techniques used to create the atmospheric view are computationally expensive. Furthermore, atmospheric representations are essentially adopted for highly detailed scenes, which are scarce at this scale. Moreover, atmospheric representations often apply a fog effect in order to mimic an artistic look. This fog tends to blur the visual, which can be an issue for seeing far elements in the scene that may be still related to the project.

Regarding the Fisher Exact Tests, a strong dependence was again observed for this contextual parameter with all the technical parameters. For this statistical test, the value "other" from the broadcasting technologies and "NA" from the Level of Detail was not considered.

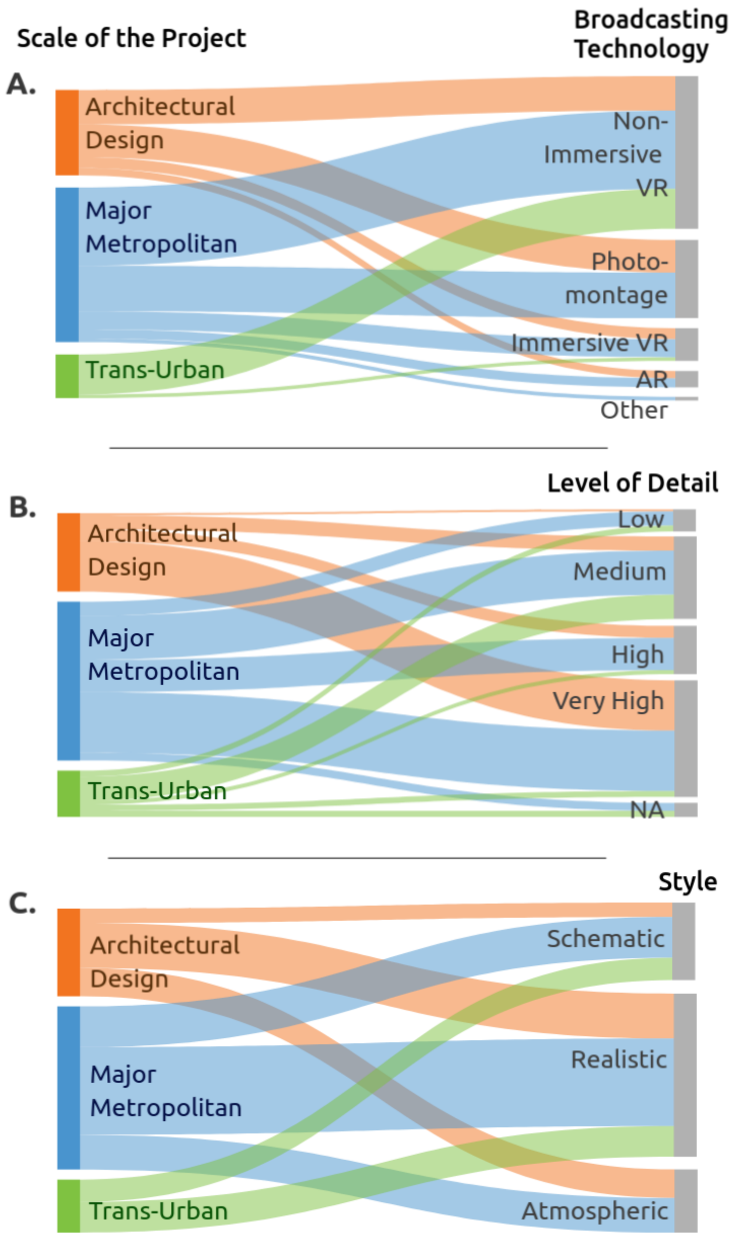

Figure 5.6. *Diagrams showing the intensity of the correlation between the scale of the project and the technical parameters. A, B, and C represent this information in the shape of a Sankey diagram which links the nodes of each parameter together. On the right of each figure, the resulting p-value of the assessed Fisher Exact Test is shown*

5.6.3.3. Participation level vs. technical parameters

The last flow diagram shows the relation between the participation level and the technical parameters (Figure 5.7). Passive involvement appears to be skewed toward more realism and non-interaction, which is not surprising. Photo-montage and immersive VR are prevalent in this passive level, which is prone to communication and immersion. This passive involvement places participants in an observer position, seemingly in the later stage of the urban project with visuals that accurately represent the future reality to support emotional bonding and engagement with the project. Also, passive involvement tends to use a high or very high Level of Detail.

The consultative level is characterized by the adoption of the full range of technical possibilities. However, this level of participation seems to be related to a medium and high Level of Detail. These two modes of detail appear to represent, on the one side, a project that is not too accurate, i.e., the project is still unclear and evolving, thus, a fixed image is not conveyed. And, on the other side, a more precise representation for projects that are less open and more definite.

The “involve+” participation mobilizes different technologies to portray the visuals. Nevertheless, non-immersive VR was mostly observed, notably because it supports a flexible implementation. Furthermore, this interactive setup adopts mainly an undefined Level of Detail (NA), which is constituted by the use of Minecraft (7 projects). This participatory level is also in line with a schematic portrayal, i.e., more abstract, supporting the introduction of salient features which help participants focus on specific aspects under negotiation during the interactive session.

Fisher Exact Tests were conducted for the broadcasting technology and the Level of Detail, However, all the conditions to conduct a Chi-Squared test were met for the style parameter. All tests were not significant for all the technical parameters. Therefore, a dependence cannot be demonstrated between these parameters. For this statistical test, the value “other” from the broadcasting technologies and “NA” from the Level of Detail were not considered.

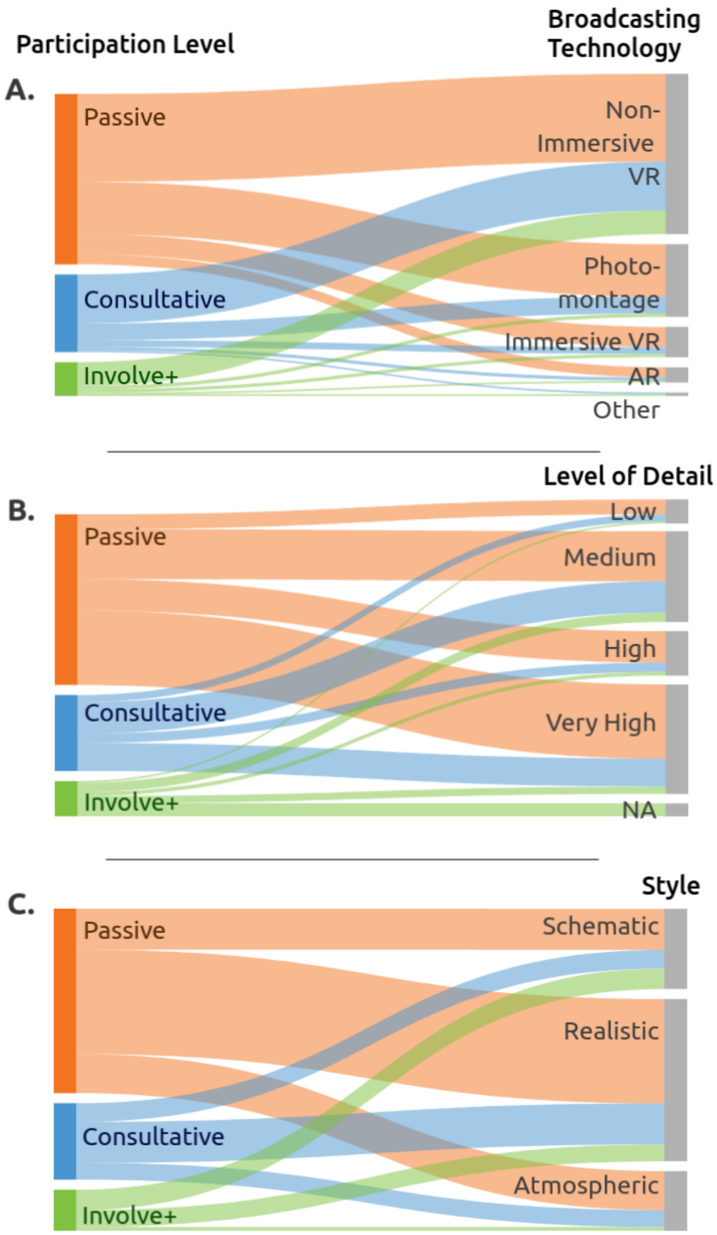

Figure 5.7. *Diagrams showing the intensity of the connection between the levels of participation and the technical parameters. A, B, and C represent this information in the shape of a Sankey diagram which links the nodes of each parameter together. On the right of each figure, the resulting p-value of the assessed Fisher Exact Test and 2 (for the style) is shown*

5.7. Discussion

5.7.1. Current Practices of 3D Visual Tools in Urban Participatory Planning

The findings demonstrated in this study show an apparent preeminence of certain characteristics of digitally generated 3D visual tools adopted in urban participatory planning. The results illustrate that these tools are mainly adopted in major metropolitan projects (at a medium scale), during the later phases of the project's design (where numerous aspects of the urban project appear to have already been defined), which leads to the passive involvement of the population with the 3D medium. This passive level of participation seems, however, to be bound to the specific usage of 3D visual tools; it indeed appears (from the articles) that most of the approaches designed by the authorities mobilize the population in a consultative context. The technical parameters resulting from these contextual categories illustrate more realism and details (in line with the later phase of the project) combined with limited opportunities to manipulate the 3D visuals (in line with the passive context of involvement). These findings are valuable because they provide a better understanding of the typical parameters in which the 3D visual tools are currently adopted. This snapshot of today's practices in participatory planning demonstrates a limited diversity of uses despite the high potential of 3D visual tools acknowledged in the scientific literature (Jacquinod & Bonaccorsi, 2019). This lack of opportunities seems to highlight a hesitancy of the institutions to adopt these visuals, which may be caused by poor knowledge of the benefits of these mediums, lack of abilities to implement them due to their inexperience with the 3D medium, or reluctance to change their current practices (Heldal, 2007; Houghton et al., 2014).

Furthermore, clear and expected relations have been established between contextual and technical parameters. For instance, the described findings showed the use of rendered, accurate and detailed 3D visuals broadcast through video or photo-montage toward the later stages of urban projects. Realism facilitates the communication, intuitive representation, and the creation of emotions that can help to promote a positive image of the future project (Hayek, 2011; Lovett et al., 2015; Voinov et al., 2018), notably by using representamen (or sign) that convey an interpretation (e.g., the depiction of a child playing that points out the safety of the space) (Raaphorst et al., 2017). Opposingly, visuals appear to be often designed with less detail when the urban scale of the project is large. 3D still requires high computational power to render, which tends to limit the size of the environment that is virtually represented. Also, the participation level "involve+" seems to adopt more schematic representations which help to develop opinions and new ideas (Hayek, 2011), and focus the attention of the participant on their tasks notably by limiting the cognitive load conveyed by the 3D (Judge & Harrie, 2020; Skulmowski & Rey, 2020). These findings of adopting abstract representation in the early stage and realistic in the later stage of the project are in line with the idea of matching the level of detail to the planning phase (Kibria et al., 2009).

One of the most striking findings of this study is the final number of articles mentioning the use of 3D visuals, which are relatively low considering the extensive search that has been conducted. This low number demonstrates poor visibility, at least in the media, which cultivates the unawareness of the benefits of 3D visual tools in participatory planning. These tools could have had a valuable role during the COVID-19 pandemic, notably regarding the simplicity and flexibility of sharing them online in a virtual setting. However, the findings did not demonstrate a dramatic rise during or after this exceptional period. Moreover, through different observations and discussions with practitioners, the authors noticed an increase in negative feelings toward the use of online settings. A certain amount of negative feedback has been raised by practitioners. One example is the low number of participants attending these online sessions, which demonstrates a failure of these online methods. Nevertheless, the online sessions designed during this period appear to mimic in-person, more typical interactive sessions, but the authors argue that this simulation of in-person settings cannot work online and that the interactive session should be shaped according to the specificity of the medium adopted.

5.7.2. The Case of Digital Twins and Serious Games

Several articles (12%) mention the use of 3D visuals via the implementation of a Digital Twin (Deng et al., 2021), or more accurately a city model (Wright & Davidson, 2020). This technology is used in the context of urban participatory planning with two objectives: (1) being able to communicate about future urban projects by sharing information and visualizing 3D models, and (2) consulting the public on specific issues. However, these considerable digital platforms are often mentioned during the first phases of their development and only scarce tangible functionalities are in production. However, these solutions that represent a digital, identical image of the city appear to be a new opportunity for the institutions to share and promote future projects or explain their development strategies to the population while being able to collect feedback on these elements through virtual geo-referenced comments shared by the population. Another benefit of these large virtual environments is the representation of the entire city; therefore, these platforms could be reused over time, limiting the need to create one-shot 3D models for each project.

Other articles (7.5%) report the use of serious games, which can be considered as an exploratory solution to engage the population, mostly in the diagnosis phase. These tools facilitate the participation and the interaction of the population while enhancing knowledge-building in the urban project (Reinart & Poplin, 2014). Most of these serious games identified in this media coverage are based on Minecraft, which allows digitally recreating a natural environment with virtual interlocking blocks. In addition, more than half of the projects adopting serious games aim at engaging children or young adults (already familiar with the game) but are often regarded as hard to reach in typical participatory approaches because those common practices are poorly adapted to their needs and competencies (Frank, 2006). The use of serious games could, therefore, provide new opportunities to digitally mobilize a population by leveraging some of the intrinsic motivational factors such as “fun” (Lotfian et al., 2020), notably with gamification mechanisms.

These two new methods of involvement represent around 20% of all the recovered approaches. A striking result is that these solutions are not primarily designed for urban planning purposes, nevertheless, they are adopted by the authorities through different projects and parameters. The other recovered 3D visual models appear to be employed only once in one-shot projects, even if these representations may be reused several times throughout the lifetime of the urban project. The flexibility offered by the city model and the serious game solutions promotes their adoption through various projects, which appears to increase the willingness of the institutions to adopt them.

5.8. Conclusion

This study aims at portraying the current applied practices of digitally generated 3D visual tools in urban participatory planning. To that end, an analysis of media coverage is conducted from January 2015 to December 2021. This investigation generates a snapshot of settings adopted by institutions in urban planning during these six years. The descriptive analysis demonstrates that the current use of 3D visual tools aspires mostly at promoting urban projects, with only rare approaches capitalizing on the added value of 3D representations for participative interaction. Therefore, it appears that these reduced applications do not mobilize the full potential of 3D visual tools, despite the technological advancements, the broad adoption of 3D visuals in other domains, and the acknowledgment of 3D benefits. The perception of these tools by the academics and their day-to-day use by the practitioners appear to not be in line, which demonstrates a gap between these two approaches to 3D visual tools.

The collected projects and their descriptive parameters (*appendix* C.1) provide a pool of past practices that support the building of a better understanding of 3D visual tools and the collection of blueprints for future development. The gathered applications show a high versatility related to the assessed contextual factors, which are also dependent on other social, financial, political, cultural, or operational factors. The findings help to link technical parameters to contextual factors, which can be used as a framework to design future approaches. However, the authors also argue that the exploration of uncommon associations of parameters could promote and improve knowledge of the practice of 3D visual tools. Furthermore, no compelling yearly patterns were identified from 2015 to 2021, even with the COVID-19 pandemic (apart from a drastic reduction in 2020), which is surprising. This stagnation in the use of 3D visuals (covered in the media) seems, hence, to convey concerns about their adoption by the institutions.

Regarding the media coverage analysis, this method gave us the opportunity to gather an unexpectedly high number of applied use cases. The collected projects were varied, even if some bias should be taken into account. For instance, the over-representation of French-speaking articles is difficult to explain. However, two hypotheses can be mentioned: (1) the gathered French-speaking media channels aggregated through the Factiva and Nexis search engines appear to have a regional scope as opposed to the English-speaking media, which seem to have a national scope, and (2) the participatory vocabulary varies greatly between projects or municipalities, the terms used by practitioners in applied urban projects may be significantly dissimilar compare to the ones adopted in the scientific literature.

The authors argue that the use of 3D visual tools could be a true asset for urban participatory planning. Effective involvement of the population in planning should be a priority to practitioners, however, limited budgets, distrust in technological solutions, lack of opportunities, or unclear guidelines may contribute to the observed reluctance in adopting 3D tools to enhance participatory approaches. Increased publication of articles about current experiences or practices of 3D visual tools in the media could promote their adoption in urban participatory planning by increasing their visibility for the practitioners.

5.9. Perspectives for the Future of the 3D Urban Participatory Planning

The results of this study emphasize the high potential of digitally generated 3D visual tools in urban participatory planning. Their adoption was observed in several, distinct settings, both contextual and technical. Two main practices were identified for these tools: the first being communication, and the second supporting participatory interactions. The communicative purpose (i.e., one-way exchange) is the most compelling goal identified in this media coverage. A notable over-representation of realism, passive participation, and goals aiming at immersion, promotion, or information was demonstrated. The scientific literature highlights 3D visual tools as assets to enhance communication about urban projects, notably by facilitating the comprehension of complex aspects of urban projects that are difficult to describe without visual tools (Bouzguenda et al., 2021; Hayek, 2011; Schroth et al., 2011; Voinov et al., 2018). The other purpose, enabling participative interactions, is less displayed in the collected media stories. Therefore, these practices still need to flourish in applied projects. Projects that have already been using 3D visual tools could contribute to an arsenal of participatory settings (technical parameters) and pioneer experiences, which may be remobilized to develop 3D visual tools in participatory planning further.

The use of technology and modern participatory mechanisms have already demonstrated their efficiency, and a citizens' appetite for tools that are straightforward and user-friendly, with a low entry cost (Bugs et al., 2010). However, the institutions appear reluctant to adopt these tools in applied projects due to a lack of clear guidelines, a plethora of settings to consider, and challenges in interpreting the collected data, which could be discouraging. Also, the benefits of 3D visual tools do not seem to be fully acknowledged by the institutions, which are stuck with other, more typical practices due to habit and concern about the adoption of new approaches. Therefore, the recollection of past experiences in the media could help to develop common imagery of the different practices of 3D visual tools in the authorities' participatory toolbox. Nevertheless, the past experiences should be cataloged and guidance for the implementation of these 3D tools should be provided. This pool of practices could help the institutions to build knowledge around the use of 3D visual tools by: aggregating similar practices (which could declutter the load of information around the adoption and use of these tools), envisioning different settings, reimplementing pioneer solutions, and gathering patterns to design new approaches.

The 3D visual tools have already demonstrated their efficiency and their added value for urban participatory planning (Appleton & Lovett, 2003; Herbert & Chen, 2015; Schroth et al., 2011). These benefits should now be translated to broad adoption of applied practices. The institutionalization of participatory practices (Blatrix, 2009) and the imperative for participation (Blondiaux & Sintomer, 2002), notably in urban planning, do not provide the institutions with a blueprint to design better participatory approaches. This lack of guidelines leads the same authorities to struggle often to engage urban dwellers (Innes & Booher, 2004). Further research in the use of 3D visual tools in participatory planning is still necessary, along with an accurate evaluation of these tools on the practices, and the planning outcomes. This research should be associated with future guidance that helps the authorities to select and design participatory approaches that fit their needs.

Chapter

6. Paper B: Challenges in Creating a 3D Participatory Platform for Urban Development

List of abbreviations for the chapter:

ICT: Information and Communication Technologies
PPGIS: Public Participation Geographical Information Systems
VGI: Volunteered Geographic Information
IA2P: International Association of Public Participation

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6.1. Preface

The previous chapter identified the technical parameters and contextual factors of 3D visual tools which are the most likely to be encountered in urban participatory planning projects. One surprising finding was the limited number of media articles collected. From the literature, adopting 3D visual tools in urban participatory planning seems to be significantly beneficial, therefore, I would have expected to gather more articles mentioning the adoption of 3D in planning processes. Furthermore, 3D visuals appear to be mostly adopted in the later stage of the urban projects, with the objective to promote the project. It is indeed acknowledged that 3D representations facilitate the immersion in a non-built future, however, these representations also ease the understanding of complex aspects of urban projects as well as create a common language to discuss the project. These observations hence highlight a gap between the potential of 3D visual tools and their use in applied projects. With this chapter, I aim to explore the reasons for this gap through challenges in the design of 3D participatory platforms. Several challenges can be assumed from the scientific literature, nevertheless, I aspire with this chapter to investigate these challenges through theories and concepts that define urban projects and public participation.

Publication and personal contributions

Chassin, T., Ingensand, J., Lotfian, M., Ertz, O., and Joerin, F. (2019) *Challenges in creating a 3D participatory platform for urban development*, Adv. Cartogr. GIScience Int. Cartogr. Assoc., 1, 3, doi: 10.5194/ica-adv-1-3-2019.

Personal contributions: formulation of research goals and aims, development and design of methodology, data collection, synthesis of study data, figures preparation, manuscript writing.

6.2. Abstract

This paper aims at underlying difficulties regarding the establishment of citizen engagement processes. The specificity of citizen engagement processes lies in their evolution over time where objectives, constraints, and latitudes of a given project influence the relevance of the tools offered to citizens. Three categories of urban projects (trans-urban, major metropolitan, and architectural design) have been described. These classes range from a local space with short deadlines to a regional space spread over several decades. Furthermore, the use of 3D platforms for a broad public is influenced by the users' preferences, perceptions, and expertise. Throughout this study, major challenges that have been experienced during the design of a 3D participatory platform are identified. They range from the issues of implementing adequate tools according to the project (temporal and spatial scalability), and the participation forms (passive, consultative, or interactive), to the difficulties of convincing the authorities to use new bottom-up methods. Finally, a conceptual framework for the creation of a 3D participatory platform has been introduced. It can be summarized by three major steps: (1) Meeting the needs of a decision maker, (2) Designing the participation tool in accordance with the context, and (3) Translating collected raw data in order to respond to the initial request.

6.3. Introduction

In 2014, more than 50% of the global population was living in urban areas. In 2050, this number will likely climb to 66%, adding another 2.5 billion inhabitants to cities (United Nations, 2014). To meet this growth current practices regarding urban planning have to change in order to be more sustainable. All around the world, several programs aimed at creating digital cities by taking into account concepts such as walkability, connectivity, mixed environments, etc. Unfortunately, public authorities are often designing and creating urban projects without any involvement of the residents. This regularly leads to a more or less violent rejection and/or opposition from the public (Subra, 2018). Classic participatory initiatives arose from the cited context. However, such initiatives are often less suited for earning the approval of the population due to the fact that shareholders participate in interminable workshops usually held during weekdays. Our past experience with participatory workshops shows that participants are mostly elderly people or/ and vigorous opponents.

Information and Communication Technologies (ICT) are one solution to broaden the potential public and to create a sustainable relationship and exchange between the government and the citizens. The concept of digital cities provides new means of bringing together the public and authorities through the use of Volunteered Geographic Information (VGI) platforms such as OpenStreetMap (openstreetmap.org), a worldwide map updated by the public where citizens are used as sensors or data producers (Goodchild, 2007). In contrast to the VGI's unoriented data production, Public Participation Geographical Information Systems (PPGIS) aspire to introduce citizen engagement in decision-making processes. Several examples exist such as FixMyStreet (fixmystreet.com) a British web application to report issues in the streets such as graffiti or cracked paving slabs. Another example is Signalez-nous (mapnv.ch/signalez/interface) a Swiss website that allows citizens to report broken street lamps, etc. Based on these concepts new PPGIS platforms addressing urban planning and decision-making have emerged. Some examples include Carticipe (carticipe.net), used in several French cities (Avignon, Paris, Strasbourg, etc.), or Maptionnaire (maptionnaire.com) which offers a map survey oriented to gather citizens' insights (Stockholm, New York, etc.). Others are implemented for research purposes such as Argumaps (Rinner, 2001), a PPGIS platform used in Brazil (Bugs et al., 2010) or Pocitové mapy (pocitovemapy.cz) an emotional mapping platform used in the Czech Republic (Pánek, 2018a).

Up to now the vast majority of these systems are based on a two-dimensional representation of the territory. We argue that the third dimension is important for territorial decision-making since it allows for the visualization of spatial phenomena such as volumes of buildings, the slope of the terrain, or infrastructure that passes under or over other infrastructure. Biljecki & al. have identified several studies which intend to design and use 3D platforms (Biljecki et al., 2015), but generally, the target users of these tools are experts. Very few tools involving 3D are focused on citizens as users (Alatalo et al., 2017). One reason for this fact might be the availability of 3D data, the difficulty to build usable 3D platforms, or concerns about using virtual environments for laypersons.

This paper aims at understanding why 3D is less used by the broad public in the context of decision-making platforms. Another goal is to identify challenges, referred to as "**C**" in the following text, for the creation of 3D platforms for public participation. This paper is structured as follows: subsequently to this introduction, in the next two sections, we address the influence of the parameters scale and time in participatory processes. Thereafter we discuss the importance of human and user factors. A conceptual framework that addresses the design of a participatory platform is described in section five. Then, we analyze ways of tackling the identified challenges. Finally, we present our conclusions and outline perspectives for future development.

6.4. Fitting the Urban Scale

In her study, N. Arab describes three contrasting categories of urban projects (type A, B, C) (Arab, 2007). Each of these categories has a specific temporal and spatial scale, ranging from a few years within a parcel to several decades in an urban area. The type A, thereafter referred as *trans-urban project*, stretches over long-term strategies regarding the reshaping of an urban area often composed by diverse cities. The B type, hereinafter called *architectural design project*, is more particular and focuses on a small parcel during a few years. The C type, the *major metropolitan project*, is more diverse, generally carried out during more than one decade. These programs aspire to reshape one or several districts of a city. Each pattern of projects affects a corresponding scale from the urban morphology: the *trans-urban type* at city macro-scale, the *architectural design type* at neighborhood-scale and the *major metropolitan type* at micro-scale (cf. Fig. 6.1).

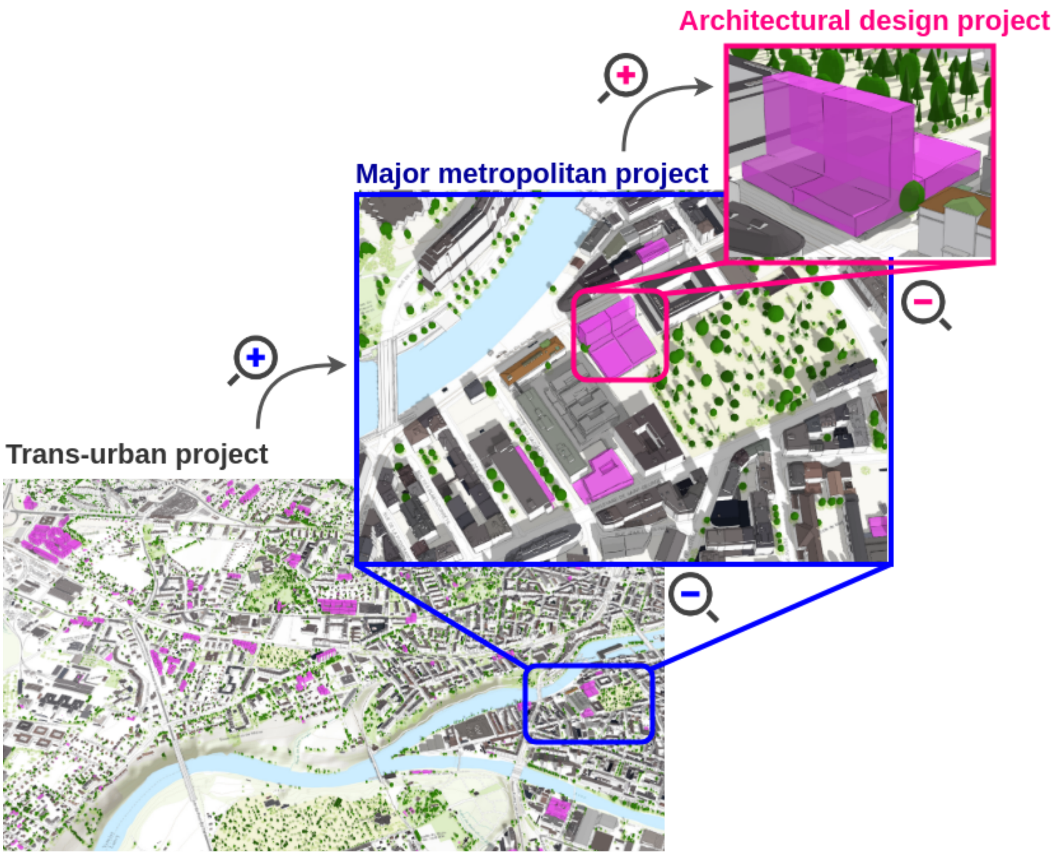

Figure 6.1. *A visual depiction of the three urban project types trans-urban, major metropolitan and architectural design described by Arab and their relationships (Arab 2007). This illustration is based on the 3D model of Geneva (sitg.maps.arcgis.com)*

However, in her paper Arab does not describe the relationship between these urban project archetypes (Arab, 2007). Fig. 6.1 illustrates the spatial extent of these types of projects. This means that generally an *architectural design project* is a measurable pattern of a *major metropolitan program* (more complex), and the latter is defined by directives dictated by a *trans-urban project* strategy. Furthermore, Fig. 6.1 highlights different perceptions according to the scale of the project type. D. Montello describes a terminology to define shifts in spatial scale: the *Figural space* is for objects smaller than the human body, the *Vista space* for areas that can be apprehended from a terrestrial viewpoint, the *Environmental space* is perceivable while moving about and the *Geographical space* for a territory which can only be understood via tools (Montello, 1993). Following this classification, the *trans-urban project* is related to the *Environmental space*; the *architectural design project* can be associated with the *Vista space*; the *major metropolitan project* type is located at the border between *Vista* and *Environmental space*.

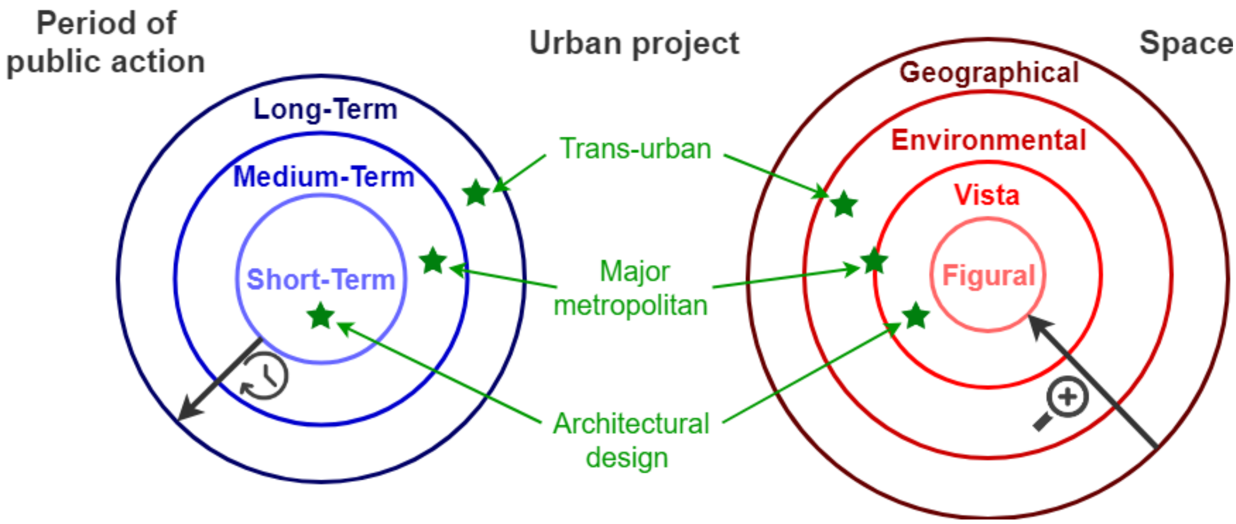

Figure 6.2. *A conceptualization of the integration of the urban project types (trans-urban, major metropolitan, architectural design) described by (Arab 2007) into the city time and space scale was introduced by (Montello 1993)*

Fig. 6.2 gives an overview of spatial and temporal scale shifts aiming at visually apprehending this concept, side-by-side. On the left, time is represented from the shortest in the center to the longest at the external boundary. On the right, spatial scales described by Montello are shown (Montello, 1993): from the less (larger scales) to the most perceivable (smaller scales). The *architectural design type* affecting one or a few buildings has a short implementation time and is included in the *Vista space*. The *major metropolitan type* is bound to a medium time period, rarely ranging over two decades. It has an established deadline. These projects are situated between the *Vista* and the *Environmental space* aim at transforming a district. The *trans-urban project* involves a long period of time, the terminology "horizon" is often used. It implies a reshaping of an urban area. These different patterns lead to the first challenge:

[C1] *How to create a 3D platform that is able to take into account different types of projects (trans-urban, major metropolitan, architectural design) with their own time and space distinctiveness?*

Citizen contributions within participatory processes are therefore shaped by time and space scales related to a project type and its embedding in the range of urban projects. Moreover, the perception of a city is personal, incomplete, and based on experience (Lynch, 1960). Users will consequently perform differently regarding mental reconstruction tasks of a city, by locating varied urban features depending on their cognition and knowledge. Chapon & al. describe three categories of environments: (1) an *unknown area*, where only a few blurry features, generally corresponding to identity-building elements of a place (e.g. political buildings, tourist attractions), can be portrayed; (2) a *loose known area*, the reconstructed map contains structural elements (such as town halls, churches, main roads, shops) and their immediate surroundings, but its representation is still imprecise; (3) the *acquired known area* which contains rich information (such as toponyms, pathways), in addition to a personal grasping of the environment (Chapon et al., 2010).

The citizens' perception is linked to their own appropriation of the territory build on a specific spatial scale. Location and dimension shifts, typical for urban projects, create a loss of reference points and thereby a feeling of disorientation. Based on these statements we define the following issue:

[C2] *How to avoid user disorientation when navigating between project scales?*

6.5. Fitting the Project Temporal Evolution

While focusing on a specific project an evolution into its parameters can be observed over time. These settings include the *latitude* (the degree of freedom that citizens possess to influence a project), the *definition* (the maturity of a project in terms of specifications, etc.), the *limitations* (constraints and objectives that are identified during the elaboration of a project), and the *shareholders*. For the development of an automobile industry project, (Midler, 1998) has established a link between the latitude of a project and its definition. Fig. 6.3 is based on these considerations where the project's flexibility decreases over time while its global knowledge grows (because of the integration of objectives and constraints). Moreover, disparity and convergence have been identified by (Arab, 2007) between project management theory and urban planning.

Several studies have considered the impact of public involvement on urban planning decision-making (Arnstein, 1969; Hart, 1992; IAP2, 2014; Pretty, 1995). The typology used within our study is described by (Pretty, 1995): seven rungs are portrayed ranging from manipulative participation to self-mobilization. Three of these participation levels have been selected from their frequent use in citizen engagement to be linked to the dynamics of an industrial project: (1) *Passive* involvement mirrors unilateral dialogue from the authorities to the citizens aiming at an explanation of the decisions that have been taken. (Arnstein, 1969) has defined this rung as information, (2) *Consultative* participation depicts an exchange between the shareholders where "people's view" is potentially taken into account by the city's representatives, (3) *Interactive* participation outlines the idea of co-design. In this case, a municipality works with its citizens to achieve and develop a project. (Arnstein, 1969) has labeled it *partnership* while the international association of public participation has defined it as collaboration (IAP2, 2014).

Figure 6.3 shows three temporal stages where the project's latitude and definition evolve over time. In the beginning, the project is not well defined yet. *Passive participation* (or information) is at this point the most suitable means of communication since it allows public authorities to communicate about the idea of a new project. Once the public is informed it becomes possible to consult the citizens about several objectives or constraints of the project in order to understand the citizens' expectations. Thereafter a definition phase begins where the latitude decreases quickly. An interactive (or partnership) public involvement can be considered here as an opportunity for the public authorities' representatives to collaborate on the design of the proposal in order to take into account the insights of the citizens. During this phase, discontinuous passive communication can be done by the authorities when new challenges are identified (e.g., environmental policies or technical obstacles). Finally, once the definition of the project is completed, a public survey is scheduled. This survey is a legal matter in Switzerland, all documentation on the project must be provided to the public for 30 days by the authorities. During this period citizens have the possibility to approve or disapprove the project by a legal authority. Thereafter the design and the definition of the project cannot evolve anymore. It is the end of consultative and interactive participation, despite the pursuit of passive public involvement. Following the public survey, a vote is executed where the electorate accepts or rejects the continuation of the project. The challenge linked to these processes is:

[C3] *How to design platform functionalities that adapt to participation level shifts and new information that has been introduced during the evolution of a project?*

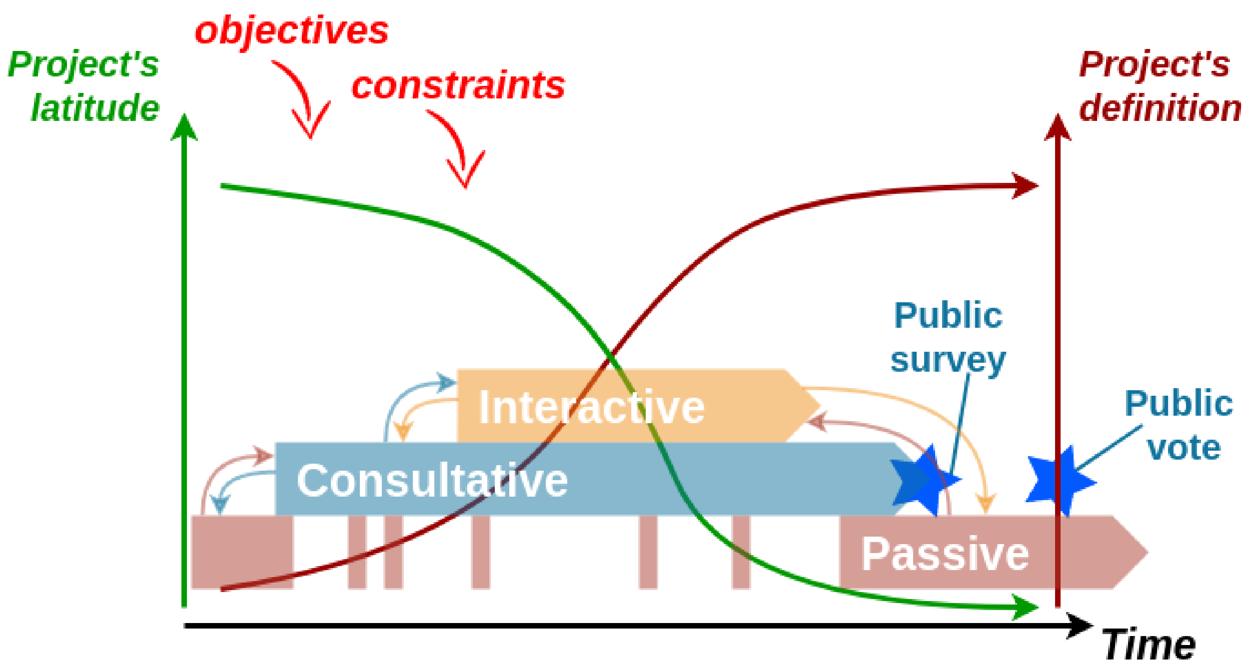

Figure 6.3*. Augmentation of the industrial project dynamics over time introduced by (Midler 1998) with citizen participation features located where they are the most efficient*

6.6. Fitting the Public/ User

In 2011, E. Lange argued that the advancements accomplished in the field of virtual reality are sufficient to adopt such technologies to landscape and urban planning (Lange, 2011). Undoubtedly, challenges are still to be addressed, but 3D scenes can be considered mature enough to be shared with a broader public. However, the authorities are still reluctant to utilize such platforms online. The pretexts are numerous. For instance, two Swiss cities (contacted by the authors) argued that the participation level of a 3D platform could decline or that the results could even be used against them. These arguments are not consistent with the results of several studies testifying to the usefulness of the third dimension in communicating with the public by lowering the participation entry cost for the citizen, and easing access to complex processes (Çöltekin et al., 2016; Liao et al., 2017). However, citizens are not effortlessly involved in these processes. In their study, Evans-Cowley & Hollander suggested that in a social network the number of “likes” can gather a social group against (or for) an urban project but it is laborious to make these “likes” visible in public hearings (Evans-Cowley & Hollander, 2010). In addition, interactive scenes establish neutrality and transparency regarding the participation; a fact that cannot be addressed with static pictures that present an author's bias by the choice of quality, perspective, or viewpoints (Downes &

Lange, 2015; Mericskay, 2013; Onitsuka et al., 2018). Moreover, interactive maps are more effective and suited for complex tasks but require more time (Herman, Juřík, et al., 2018). Based on these considerations we can identify the following question:

[C4] *How to convince authorities that their accountability and reliability can be increased by a public participatory 3D platform?*

6.6.1. The User Navigation

Several studies (Bowman et al., 1997; McCrae et al., 2009; Moya et al., 2014) have attempted to create 3D navigation metaphors based on the two aspects that balance navigation mechanisms in virtual environments: (1) movement (motion), (2) wayfinding (cognition) (Jankowski & Hachet, 2015). (Jankowski & Hachet, 2015; Mackinlay et al., 1990) listed some techniques from walking to flying analogies in an automated or manual mode. Each navigation method has its benefits and drawbacks. For instance, automated movement helps to ease the use of 3D scenes for laypersons, however, it reduces user engagement (Parush et al., 2007). In contrast, experts prefer manual control due to higher accuracy and velocity (Moya et al., 2014). Therefore, navigation relies on a user's past experiences and preferences. Moreover, a city model contains numerous scales that motion depends upon. Based on this assumption, in 2009, Zhang suggested a multi-scale displacement managed by an avatar changing in size: the taller, the faster the user can move through the virtual scene (Zhang, 2009).

6.6.2. The User Perception

Numerous factors can guide a user to apprehend a virtual environment such as tips on the available features and their function, a “you are here” arrow, highlighted interactive elements, etc. One major challenge in 3D visualization is data overload leading to errors because of a loss of readability (Juřík et al., 2016; Seipel, 2013). To limit this lack, abstract representations are used (Alatalo et al., 2017). This conceptual depiction can be used to collect information (such as insights, emotions, opinions, or problems) and to empower a robust basis for discussion or communication aiming at a specific topic (Hayek, 2011). In contrast, photo-realistic models or experimental representations are more intuitive (Tutzauer et al., 2016), linked to emotions (Newell & Canessa, 2018), and considered to be more natural (Stachoň et al., 2018). However, excessive realism leads to an uncanny feeling, therefore mixed representations combining abstraction and verism have proved their efficiency (Appleton & Lovett, 2003; Lokka & Çöltekin, 2018).

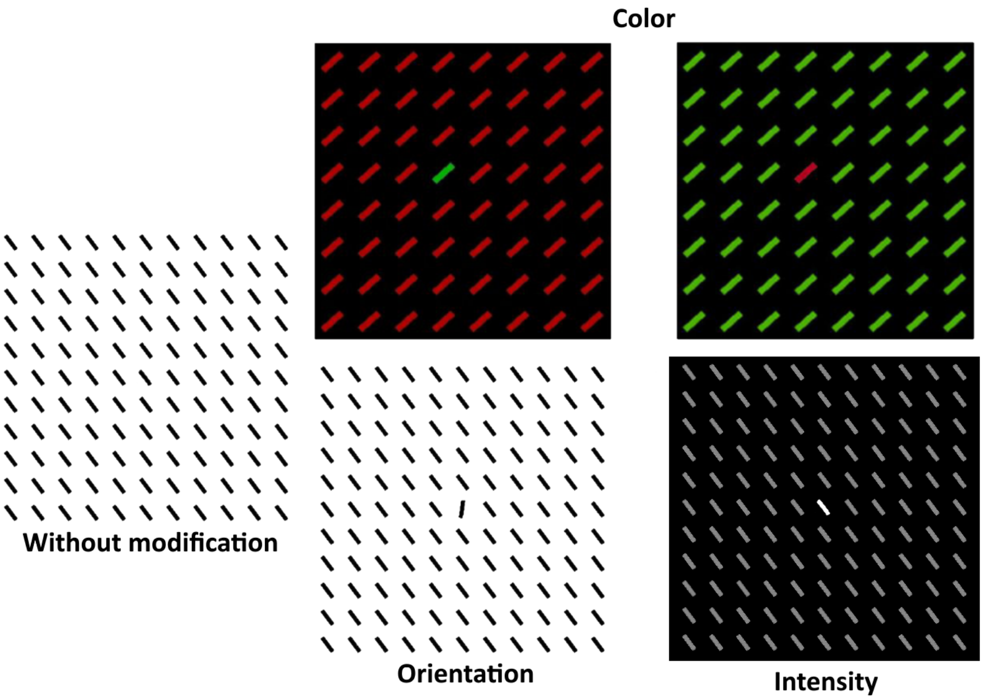

Figure 6.4. *Pop-out effects are induced by color modification, intensity, or orientation from (Martin 2016; Chiaramonte 2007)*

To clarify visualization comprehension, techniques based on saliency maps are applied such as the "pop-out" effect shown in Fig. 6.4. This concept aims at creating a contrast between an element to underline from its context. The pop-out is built on four parameters: a fluctuation of color, intensity, orientation (Chiaramonte, 2007; Martin, 2016; Wolfe & Horowitz, 2004) or motion applied to the object (Regan, 1986). However, working with a virtual city model where buildings and street furniture are accurately located, animating an element is irrelevant. In addition, rotating an item is geographically false, and in a situation where all objects have various orientations, a "pop-out" effect would have no impact. Therefore, only two parameters are feasible: color and intensity. An example is shown in Fig. 6.5.

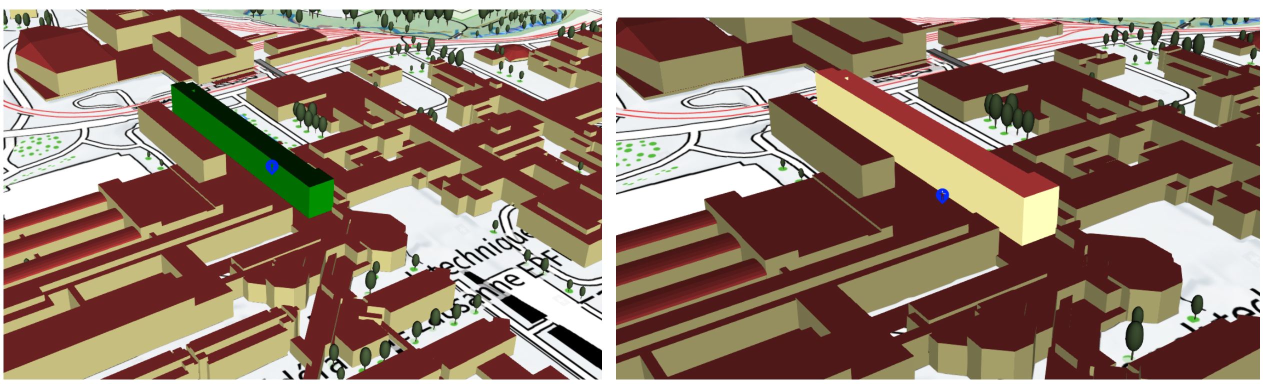

Figure 6.5. *Pop-out effect on a city model from our 3D participatory platform*

Factors such as expertise, age, background, or preferences have a direct influence on the user's spatial features perception (Newell & Canessa, 2018), nevertheless, tools exist to limit their impact. The following challenge can be put forward:

[C5] *How to design a system that takes into account user features in order to adjust the virtual scene accordingly?*

6.7. A Conceptual Framework for 3D Participation Platform

Participatory processes are regularly built around ethical, political, and economic factors which affect communication dynamics. The starting point of our framework is a request by a decision maker about an urban project (Fig 6.6). The first step aims at translating his needs into a list of understandable information that can be surveyed by the citizens. The urban project pattern and its temporality should be addressed at this stage in order to apprehend the scope of the context which is defined by parameters such as public latitude, parameters in negotiation, participation type (passive, consultative, interactive), spatial scale, etc. Descriptions of this step can be found in the literature as purpose and context comprehension (also defined as *when?*) (Bryson et al., 2013; Lovett et al., 2015; Marzouki et al., 2017). Once the needs are formalized, an opinion poll attempts to delimit the scope of participation, adopts the communication tone with citizens, designs a scenario, and defines rules. Then, this participation schema has to be technically implemented by selecting interactions between the platform and the users, the available tools, and visualization settings (level of detail, transparency, displayed elements, realism, etc.). This step illustrates two elements specifying the content and symbology (or what?) and identifying appropriate participation tools (or how?) (Bryson et al., 2013; Lovett et al., 2015; Marzouki et al., 2017). These technical choices lead to the creation of a unique dynamic, where the platform manages iterative interactions between citizens/users, the 3D scene, and the translated requests from the authorities. Emotional maps (2D geo-tagging of personal experiences) (Pánek, 2018a), argumentation maps (public geo-discussions) (Rinner, 2001), compare and vote on 3D mock-ups (agency9.com), or geo-referenced picture sketching (unli-diy.org) are some examples for potential use and design alternatives. A large amount of raw data from the platform are gathered into a database, introducing a new issue:

[C6] *How to handle raw data from participation.*

The collected information is not usable as it stands by authorities to take advised decisions. The last translation step is required to transform raw data into convenient, transparent, and neutral information for the decision maker. Data visualization and analysis can enhance outcome interpretations. Heat maps illustrating opinions (positive or negative) or categories (security, leisure, meetings, ...) are commonly employed. But other witty portrayals emerge, such as positive and negative discussion sunburst charts sorted by insights (cartodebat.com), or indicators regrouped on a dashboard.

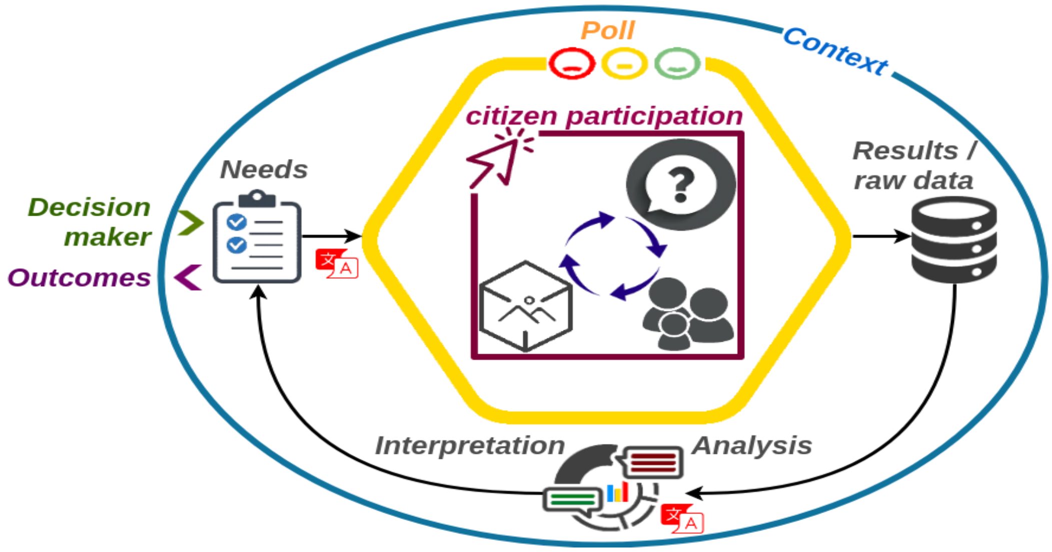

Figure 6.6. *Framework illustrating the design of a 3D participatory approach. This framework emphasizes two crucial steps of translation: from the authorities' needs to the tasks that the participants have to address, and from the participatory data to adequate insights that can be used for decision-making*

6.8. Recommendations Addressing Identified Challenges

The challenges sketched in this paper can be addressed by three precepts: (1) *Responsiveness*, platform shapeshift in accordance with the context **[C1,3,5]**, (2) *Portrayal*, understandable data visualization **[C1,2,3,5],** and (3) *Accountability*, honest and transparent outcomes **[C4,6]**. The purpose of this section is to draw recommendations that should tackle each issue.

[C1] Based on the work of (Alexander et al., 1977), we suggest using the design pattern theory. Each project type has its specificities (time & space), identifying a motif applied in accordance with the situation that should simplify the platform design. Moreover, the scene portrayal should tend to be an abstract representation for a large scale and a realistic depiction for a smaller scale. Project surroundings are essential for 3D understandings, however, an omission or a verismo representation introduces confusion in the user's view.

[C2] Design a scenario that eases participation for users. For each step of the scenario, parameters and instructions (cameras, space limitation, representation, etc.) could be described to the participants, informing them when a scale is shifted. Static structural city elements can provide robust landmarks to the user. Another method to keep the user perspective is to apply intermediate representations demonstrated in 2D (Dumont et al., 2018).

[C3] Interaction degree and scene representation should vary according to the circumstances. New elements could be highlighted using colors, details, or saturation. Interaction freedom should depend on the degree of participation. For passive participation, we advocate for free navigation in the 3D scene and for controlled information display. For a consultative level, we suggest adopting 3D geo-questionnaires, categorized landmarks, or geo-discussions (Haklay et al., 2018). For an interactive degree, we recommend collecting participant insights via sketches, 3D mock-ups, or spatial descriptions.

[C4] Designing a flexible and durable 3D platform allows for reusing it in different contexts and therefore reduces its cost. Transparency and neutrality, the main concepts of public participation, lead to increasing authority's accountability and project acceptance rates. Encouraging the wisdom of crowds and public judgment deepens the outcome value (Brown, 2015). Furthermore, the inclusion of gamification elements such as stories or rankings is likely to increase the number of users in participatory processes and the number of posts pe rusers.

[C5] Reality 3D abstract representations are shaped by numerous factors related to users (expertise, age, background, color blindness), scales, objectives, contexts, and resources (Warren-Kretzschmar & Tiedtke, 2005). They provide a specific scene understanding which may differ according to the user. Decisive elements for public judgments should not change, however, this does not apply to every component of the scene. Thus, user preferences could be taken into account. Based on the work of S. Christophe, we recommend using a dialogue agent that will identify user specificities in order to depict a 3D scene in accordance with his own taste and needs (Christophe, 2008). For instance, a fixed easy-to-control camera view will be provided to a layperson.

[C6] Providing understandable, neutral, usable, and transparent outcomes from participatory processes are fundamental. These aspects derive from a valuable dataset that has to be exhaustive, up-to-date, and accurate. Data collected from the platform (user information, interactions, and inputs) are difficult to process. Modern big data techniques could be applied in order to classify and visualize this kind of information. We also suggest using deep-learning approaches, natural language processing, image classification, etc.

6.9. The Future of Participatory Processes

The collected data (maps, a geospatial database, indicators, comments, etc.) provides input for a Strengths/ Weaknesses/ Opportunities/ Threats (SWOT) analysis, for city strategies and urban studies (Pánek, 2018a). These participatory tools advertised to a large public led to a democratization of the citizen's attention concerning urban planning. Additionally, participants' insights counterbalance urban planner studies. Indeed, the expert vision is efficient but specialized, involving a propensity of seeing public spaces in a professional approach. On the other hand, the implication of non-experts in public engagement processes leads to the identification of opinions regarding city features that experts can miss.

Fig. 6.7 shows another interest in using a 3D participatory platform: its output can be used as input for other participatory tools. Following a request from the decision maker, an opinion poll is usually performed. This step allows focusing on future participatory discussions by categorizing the expected answers of the citizens. The most common answers are adopted for the next step in the process. Thereafter, we suggest taking advantage of the participation's various shapes such as transect walks (a group of participants follows a pathway in the city to argue about hot-topics), on-site workshops or public hearings, web tools (3D virtual globes), or others means which should if operated simultaneously, enhance the overall outcomes. The iterative use of the different participatory forms increases accurate feedback for the decision maker's initial requests. In addition, potential biases introduced by the 3D platform or the other participatory means can be limited by combining diverse means. For instance, 3D views which can be considered attractive to younger people tend to exclude elderly people. However, this tendency is counterbalanced by public hearings or urban promenade attendances where the elderly are over-represented. Moreover, a mix of participation tools allows for a democratization of public engagement and therefore could help to reach a larger part of the population.

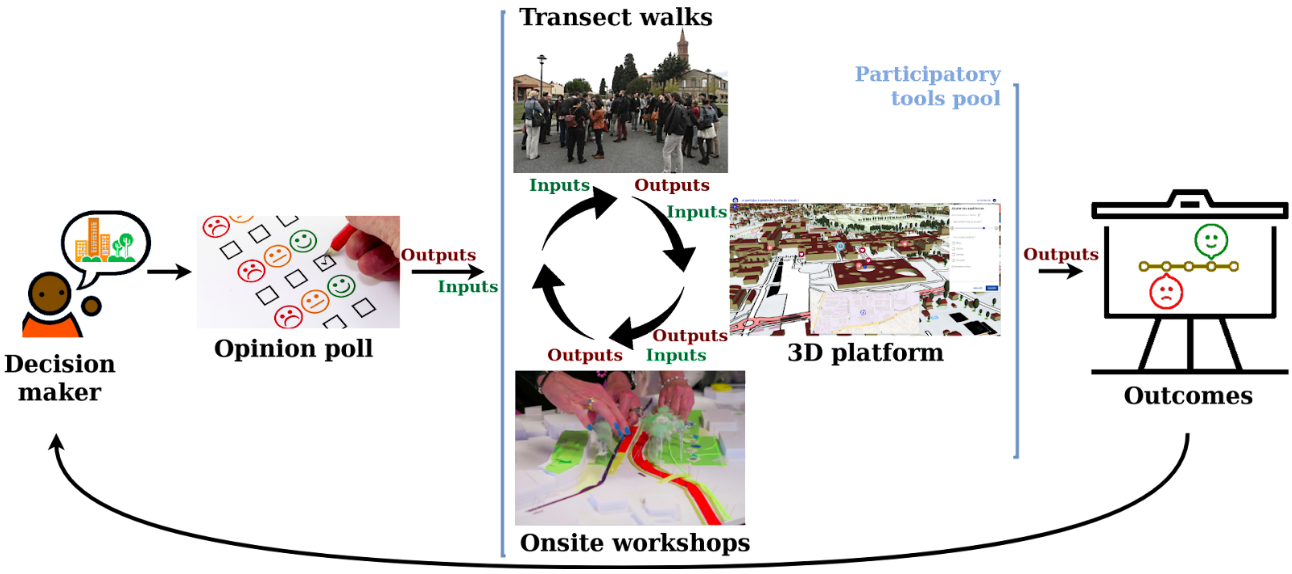

Figure 6.7. *There is no fit-all-situation participatory medium. Therefore, the combination of on-site workshops, transect walks, a 3D platform, and other mediums should be at the core of every citizen engagement approach to increase representativity and inclusivity*

6.10. Conclusions

The described challenges extend the idea of participation processes. They take into account varying criteria such as spatial/ temporal scales, citizens/ users, and data processing. To confront these challenges a flexible and durable platform needs to be developed. Virtual globe technologies allowing scale changing and personalized functionality are feasible solutions. Pre-built features can be dynamically activated and adapted depending on the project.

The concept of "digital cities" changes the way public administrations operate. The fact that new tools offer ways for citizens to react and take positions represents a shift from top-down to bottom-up approaches. This concept places citizen and participatory processes at the heart of the decision-making process. However, many existing tools are still not suitable for these new dynamics. Therefore, new participatory platforms should be developed and included in citizen engagement processes. These kinds of neutral tools can help the citizens to understand a project's objectives and constraints and to guide them to create their own opinion in order to influence political decisions. On the other hand, such platforms can be helpful for decision makers to make decisions that are accepted by a majority of the population.

Chapter

7. Paper C: Impact of Digital and Non-Digital Urban Participatory Approaches on Public Access Conditions

List of abbreviations for the chapter:

EO: Executive Order
SPA: Spatial Planning Acts
OECD: Organization for Economic Co-operation and Development
GIS: Geographic Information System
VGE: Virtual Geographic Environments
MP: Master Plan

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7.1. Preface

The two previous chapters focus on the application of 3D visual tools and their design (with virtual geographic environments). The findings emphasize that a multiplicity of factors and parameters have to be considered in the adoption of the tools in urban participatory planning. This variability, connected to their highly complex implementation may contribute to the rare examples observed in applied projects. The adoption of 3D visual tools, based on a virtual geographic environment, can be implemented through two main settings: offline, during a typical (in-person) participatory approach such as a workshop, focus group, or public hearing; or online, within a digital participatory process. These settings are not mutually exclusive; however, decisions about endorsing online/offline or even 3D/not 3D will ultimately shape the participation and its outcomes. Several studies have explored the benefits of adopting one or the other, but these investigations struggle to recognize the crucial relationship between the medium adopted in participatory sessions and the targeted public. Therefore, in this chapter, I suggest a new perspective through access dimensions on the relationship between the affected public, participants, and participatory medium.

Publication and personal contributions

Chassin, T., Cherqui A., Ingensand J., and Joerin F. (2021). *Impact of Digital and Non-Digital Urban Participatory Approaches on Public Access Conditions: An Evaluation Framework*, *ISPRS International Journal of Geo-Information* 10, no. 8: 563. doi: 10.3390/ijgi10080563

Personal contributions: formulation of research goals and aims, development and design of methodology, data collection, creation of the framework, synthesis of study data, figures preparation, manuscript writing.

7.2. Abstract

The gradual institutionalization of public participation increasingly compels local authorities to partially share their power over the transformation of urban areas. The smooth running of a participatory session is based on selecting the appropriate type of interaction, or medium, which supports the local authorities to reach and interact with a targeted public. However, local authorities often appear unfamiliar with the organization of interactive sessions with the population. This article introduces an evaluation framework that focuses on the access conditions of participants to the sessions of interaction. This novel perspective aspires to assist the local authorities in their decision to adopt a participatory medium (or method of interaction). Seven dimensions are investigated for this aim, namely accessibility, availability, adequacy, affordability, acceptability, awareness, and attractiveness (the last dimension is introduced in this article). In light of two real case scenarios that occurred in Western Switzerland, the use of the access framework is investigated for two potential purposes: (1) supporting the choice of a medium for an interactive session according to the urban project's context and the targeted public; and (2) improving future participatory approaches by assessing the representativeness of participants attending a past session in comparison to the originally targeted public.

7.3. Introduction

Over the past thirty years, the necessity of public participation and its institutionalization has been a growing challenge for governments (Blatrix, 2009). This challenge is currently being accelerated and transformed by the integration of digital technologies (Jho & Song, 2015). In the context of local urban planning, public participation, which fluctuates between negotiation and information (Arnstein, 1969; Torre & Beuret, 2012), is often multi-dimensional, both in the structure of the involvement of citizens and in the medium adopted by the authorities to broaden its reach (Hrivnák et al., 2021). Apprehended to lose power over the decision-making process (Blatrix, 2009), but also unsuccessful in the organization of direct interaction with the local population (Baker et al., 2007; Innes & Booher, 2004), elected officials often find themselves endorsing approaches designed by consultancy firms. However, these private actors are often foreign to the territory and are not as familiar with its specificities as the local authorities are. These social and spatial characteristics are a significant issue in participatory approaches (Li et al., 2020). The local authorities, with their detailed knowledge of the problems of the area in question, should therefore be more qualified to identify the targeted stakeholders for a participatory approach.

The identification of the appropriate population, known to add value to an urban planning project, meets two potentially antagonistic objectives: the legitimization of the project as supported by elected officials (Fung, 2015), and the contribution of citizen expertise, i.e., the “citizen knowledge” (Sintomer, 2008). To reach this targeted population by the participation process, the urban project managers (and the local authorities) need to identify the aspects of the project, which will be subject to negotiation in addition to the individuals to invite. For instance, considering a construction project for a center devoted to disabled senior citizens, these future users should be the target public of the participatory approach. The approach needs to be structured to mobilize this specific population. To encourage the targeted stakeholders (the project’s future users) to attend a participatory session, project managers must adopt mediums (pictures, maps, digital or physical mock-ups, questionnaires, transect walks, 3D platforms, etc.) that will place the approach within the right context.

This article addresses these mediums (i.e., methods of interaction), for structuring citizen participation, from the perspective of the population access conditions. This specific lens investigates one of the numerous aspects of urban participatory approaches in detail. Hence, the tool introduced in this study should be included, not in a self-sufficient evaluation, but in a holistic evaluation that takes into consideration additional dimensions such as the overall cost of the approach, the political situation, the risks, and the cultural context. After defining the layout of public participation, this article highlights the fundamental issues of citizens’ access to the participatory process according to the medium selected by the planners and/or decision makers. This contextualization of the stakes and challenges in designing participatory approaches supports the elaboration of an evaluation framework regarding access conditions of the public, and the leverages which can be implemented to foster its involvement. Increased knowledge of the relationship between methods of interaction and public access could facilitate the negotiation between planners and decision makers in the medium selection, ultimately leading to an improved involvement of the targeted stakeholders, and their equality towards participatory approaches. This framework is then discussed using the examples of two participatory approaches articulated around two urban planning problems in Western Switzerland. Finally, the article examines the implied synergy between digital and non-digital mediums, besides their purposes as a vector for facilitating the engagement of the targeted public.

7.4. Public Participation Definition and Citizens’ Empowerment

In all public domains, any approach that looks for citizens’ inclusion in decision-making implies a lengthy process (Lawrence & Deagen, 2001). However, the participatory process should not be regarded as an additional layer of complexity in policy-making, but as an essential step to co-design a political decision. This study focuses on public participatory approaches initiated by authorities in the context of urban planning problems. We illustrated the components that compose these processes in Figure 7.1. An interaction session happens at a fixed time at a set place (real or virtual), during which citizens and authorities exchange information through a medium. A single session is a part of a broader process that will generate deliverables (e.g., reports, or indicators) for an urban planning problem. Each session has a specific scope that aims to address particular components of the overall problem. These separate steps aim at reaching a particular audience (i.e., the targeted public), that should be adequately represented by the participants of the session.

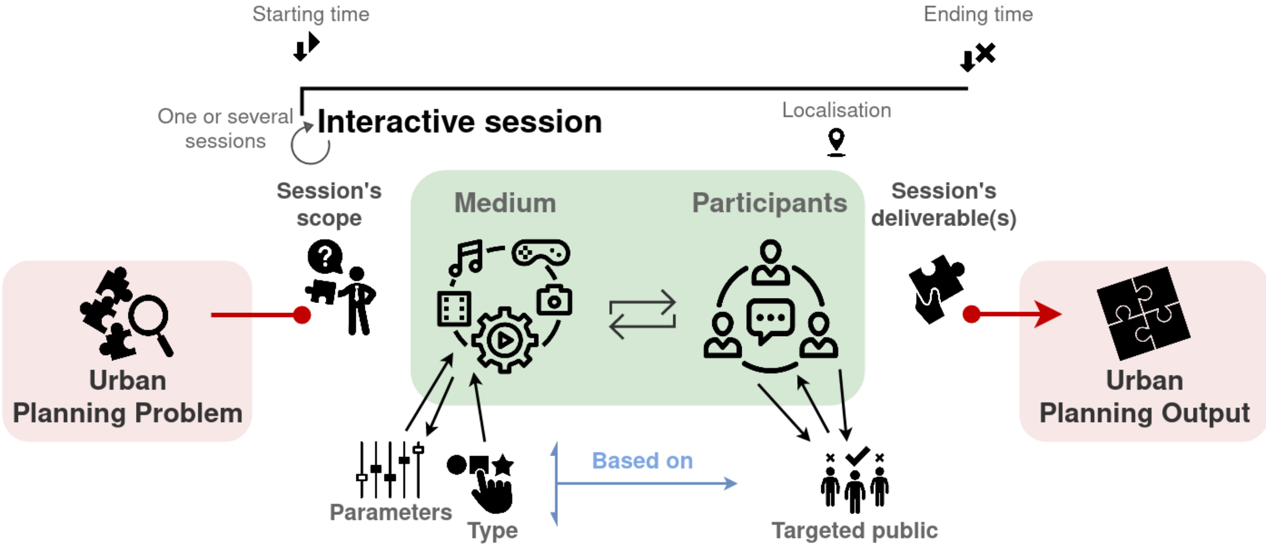


***Figure 7.1**. Schema of urban public participatory approaches initiated by authorities.*

7.4.1. Public Involvement in Urban Decision-Making

Interactive sessions with citizens are increasingly adopted to address urban planning problems. This dynamic generates dialogues between the citizens who are involved as local stakeholders/experts because of their knowledge derived from experiencing their neighborhood (Akbar et al., 2020), and the local authorities in charge of urban development. Nonetheless, local officials retain the legal power of decision-making.

Two concurrent phenomena characterize public participation in urban decision-making: (1) the stakeholders' need to participate in the decision, and (2) the compulsory practice of the stakeholders' involvement, enforced by national spatial laws, and executed by local authorities (Baeckelandt, 2020). Several examples demonstrate this second phenomenon in the western world that is wealthy enough to address these issues. In the United States, the establishment of the first Executive Order (EO), signed by former President Barack Obama in 2009, was endorsing the creation of the Open Government Initiative, which contributed as a first step to reinforcing the public's judgments in local decision-making (Obama, 2009). However, this EO does not define the approach to gathering the public's knowledge through citizen participation. This lack of detail is also observed in several Spatial Planning Acts (SPA) enforcing citizen participation in the planning processes. Such is the case in Quebec with the 2018 SPA (available on legisquebec.gouv.qc.ca, last accessed on May 17, 2021) and its "dissemination of information, and consultation and active participation of citizens" (R.S.Q., c. A-19.1, art. 80.1); in France with the 2014 Lamy Act (available on legifrance.gouv.fr, last accessed on May 17, 2021) where the territory needs to be "co-constructed" with inhabitants (LAMY, n°2014-173, art. 1 et 7); and in Switzerland with the 2019 SPA (available on admin.ch/opc, last accessed on May 17, 2021) where citizens should be able to "participate adequately" in decision-making (LAT, RO 700, art. 4). These SPAs leave vast spaces for interpreting participatory processes, which leads to entrusting the local political actors with a decisive organizational choice over the design of the participatory approach. However, this empowerment can potentially be exploited to manipulate the population and extend the power that the authorities have over the decision.

The gradual institutionalization of public participation also does not clarify the degree of delegation power, which has been measured in the literature through the different scales of citizen participation (Arnstein, 1969; Torre & Beuret, 2012). However, nowadays both politicians and literature acknowledge the necessity of reconsidering the modes of citizen involvement in projects that have a territorial impact, such as urban projects (Dechézelles & Olive, 2016; Fortin & Fournis, 2014; Saucier et al., 2009). Such modifications of the peoples' living places (Dechézelles, 2015; Sebastien, 2016) can lead to strong opposition if established without considering the project's social acceptability, based on stakeholder participation (Fortin & Fournis, 2014; Wüstenhagen et al., 2007).

Regarding a public decision, if political-administrative actors decide or are obliged to share their decision-making power extensively, this does not automatically lead to the participation of a broad population. Several common obstacles include elitist control and alliances (Martínez, 2011), lack of flexibility in urban procedures and non-integration of the deliverables from interactive sessions in decision-making (Hasler et al., 2017), time limitation (Evans-Cowley & Hollander, 2010), acquiring the means to participate (Leao & Izadpahani, 2016), seating limitation and resources (Pickering & Minnery, 2012), participatory abilities (Baker et al., 2007), etc. All of these obstacles constrain the involvement of actors. New participatory mediums are thus being developed to partially address these barriers to promote democratized participation, i.e., reachable by everyone.

7.4.2. Digital Technologies to Support Participatory Approaches

In recent years, digital participatory mediums have become increasingly used. Since 2008, through the Civic Tech boom, a plethora of digital tools have aspired to revisit existing institutional processes (Civic Tech Field, 2019; Knight Foundation & Rita Allen Foundation, 2017). These tools act as modern communication methods between authorities and citizens and deliver more direct, efficient, transparent, and fairer decision-making according to the founders of various Civic Tech companies (Brabham & Guth, 2017). This rise of Civic Tech coincided with the transition to a social web, namely Web 2.0 (O'Reilly, 2007). This web era allows users to consult web pages that create social interactions and networks between users, which implies the promotion of new means to participate. These tools are designed to facilitate the interactions between stakeholders and improve the feedback response time from the authorities, thus reducing "participation fatigue" (OECD, 2004). Examples of digital platforms enhancing the participation of the public have been evaluated and classified in the literature according to several factors, such as implemented functionalities, level of citizens' empowerment, and pricing strategies (Falco & Kleinhans, 2018; Gün et al., 2020).

Among the technical pluralism of Civic Tech (Schrock, 2019), Geographic Information System (GIS) tools appear valuable for urban participatory approaches. Indeed, the benefits of 2D GISs have been demonstrated for urban planning for many years (Al-Kodmany, 1999; Talen, 2000), in particular, due to their ability to efficiently process and display geo-referenced content (Fechner & Kray, 2014; Rinner, 2001; Zhang, 2019). Mixing public-focused Web 2.0 components with GIS tools (e.g., Public Participation GIS) appears to be an opportunity for the authorities to gather an immense collection of citizens' feedback and to conduct broad surveys (Czepkiewicz et al., 2018; Haklay et al., 2018; Pánek, 2018a), i.e., to anchor citizens' local knowledge in its spatial dimension (Brown & Kyttä, 2018). Early adopters have already acknowledged the usefulness of digital mediums in participatory approaches. According to the literature, users are eager to participate more often in collaborative online-mapping platforms with a user-friendly interface and a low entry cost (no software installation nor background knowledge required) (Bugs et al., 2010). New integrated methods including stakeholders throughout projects (from the design to the implementation) also emerge to produce local knowledge via participatory and collaborative mapping, notably in environmental management (Liu et al., 2018; Pedregal et al., 2020).

Besides these 2D digital mediums, Virtual Geographic Environments (VGE) and their third dimension have the potential to strongly impact the practice of urban participatory approaches. This additional dimension has many advantages, as described in the literature, including more accessible communication, intuitive representation, a better understanding of volumes, and increased immersion (Çöltekin et al., 2016; Jacquinod & Bonaccorsi, 2019; Teyseyre & Campo, 2009). A better self-projection within a future urban project facilitates its overall understanding; therefore, VGEs appear to be an asset for achieving democratized citizen participation. A few guidelines exist in the literature about the representations and the functionalities that enhance urban participatory approaches (Judge & Harrie, 2020). However, the third dimension is employed only seldomly in urban projects and participatory approaches. A few examples are present in the industry CityPlanner, NeoCity, and the scientific literature (Alatalo et al., 2017; Hu et al., 2015; Virtanen et al., 2018).

Although Civic Tech leads to new opportunities in representation, interaction, and promotion of project elements with the introduction of new mediums, the significance of these stimuli (profitable or unprofitable) is not yet assessed regarding the democratization of urban participatory approaches. Numerous limitations prevail in the adoption of digital technologies, such as the blurring of the distinction between experts and laypeople, the digital divide, the decision-making based on citizens' contribution, self-selection bias, laborious data processing, data security, junk information, and technical performance issues (Alatalo et al., 2017; Çöltekin et al., 2016; Hasler et al., 2017; Kahila-Tani et al., 2019; OECD, 2004; Sieber et al., 2016). Despite the evidence that suggests that digital technologies represent one of the solutions that could bridge the gap between traditional tools and modern participatory approaches, providing a broad population with access to participatory processes does not seem entirely addressed by this digital medium.

7.5. Access Barriers in Participatory Approaches

In addition to outlining the foundations of urban participatory approaches, the previous section emphasizes the central position of the citizens/participants. In recent years, numerous governments have understood that building the public's trust in governance is achievable by being more transparent, responsive, and accountable. These values are notably advertised by the Open Government Partnership, and its declaration is now endorsed by 75 countries. Therefore, they are promoting the adoption of cooperation with citizens, notably in urban decision-making. Moreover, the involvement of assorted participants leads to the wisdom of the crowd, i.e., "the Many" surpass "the Few" with relevant and accurate contributions to any problem (Surowiecki, 2004). This concept emphasizes the significance of the group's heterogeneity and the individuals' independence in terms of values, experiences, and points of view. The participants' diversity in urban participatory approaches increases the number of different opinions, ideas, insights, choices, and aspects. A wider variety of participants could be reached via adopting various mediums or providing distinct interaction modes.

From the authorities' perspective, this diversity means being able to effectively enroll 'the public', i.e., to reach the targeted public (also known as appropriate stakeholders) for the scope of an interactive session (Barnes et al., 2003; Bryson et al., 2013). 'The public' differs in each context, and it englobes a full range of characteristics: elderly, youth, female, opponents, workers, residents, etc. The authorities seek to mobilize these targeted stakeholders to attend specific interactive sessions. This drive to action passes through the choice of a medium (Brody et al., 2003).

However, today the typical participant is frequently portrayed as a senior, male, educated, and financially secure (McLain et al., 2017). The over-representation of these socio-demographic characteristics in interactive sessions is not a choice artificially made by the authorities, but the result of social positioning, i.e., a legitimacy to act. Consequently, the more individuals feel legitimate to act (interest in the issue, users affected by the project, involvement in public life, member of an associative network), the more they regard their voice as legitimate. One of the best-known illustrations of this phenomenon is the "Not In My BackYard" concept (Devine-Wright, 2005). Furthermore, other social characteristics, such as job, income, capital, and speaking skills are also reinforcing this participation, which leads to the over-representation of a middle to upper social class in participatory approaches.

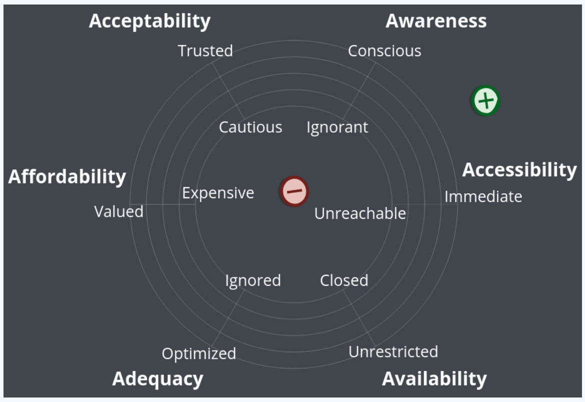
The scope of the session is highly versatile and requires appropriate stakeholders. Therefore, participants in different sessions should not be analogous. This gap between 'the public' and the participants attending the interactive session highlights a lack of representativeness, which is a critical parameter of public participation (Rowe & Frewer, 2000). Low representativeness—linked to analogous socio-demographic characteristics or participants dissimilar to the targeted stakeholders—can lead to a bias (implied by the dominance of one group of stakeholders), the fatigue of the participants, and thereby to a decrease of the legitimacy of the decisions that have been made based on the results of the interactive session.

The choice of the medium used in an interactive session includes and excludes diverse parts of the population. Each medium has its benefits and its limits towards the citizens and the overall participatory approach in terms of location, duration, digital divide, communication, number of participants to manage, data, etc. These factors shape the collaboration between the authorities and 'the public' in terms of representativeness, which is conditioned by how each individual in the population is affected by the specificities of the selected medium. In this article, we argue that these hindrances can be identified by evaluating the population's access to interactive sessions supported by the medium used in these sessions. We introduce a framework that aims to assist the authorities to evaluate the population's access according to any type of participatory medium used in interactive sessions. We argue that the evaluation of public access, if put into practice, leads to improved representativeness. This framework can be useful at two stages: (1) before the participatory phase, to choose the medium according to the context and the targeted public (e.g., as a checklist of access issues to be considered), or (2) after the participatory phase, to assess the participants' representativeness in comparison to the public targeted by the authorities (continuous improvement process). The concept of access is well described in the medical literature from a healthcare/patient perspective. Levesque and al. identified more than ten articles addressing this topic through the definition of dimensions (Levesque et al., 2013). This inspiration from a medical background is relevant, considering the relation of healthcare vs. patients as state service vs. citizens.

In experimental medical sciences, the concept of access is defined using six dimensions: (1) accessibility, the distance between the location of the service and the customer; (2) availability, the ratio between volume (needs) and resources (capacity); (3) adequacy, the fit of the service to the client; (4) affordability, the service cost for the client; (5) acceptability, the customer opinion about the service; (6) awareness, described as the publicity of the service (use, role, goals, user target, etc.) and the information monitoring (Penchansky & Thomas, 1981; Saurman, 2016). In the next section, we transfer these dimensions to an urban interactive session point of view.

7.6. A Framework for Evaluating Citizens' Access

This article aims to develop a framework that supports the evaluation, assessment, interpretation, and comparison of the access dimensions that are implied by the practice of a medium (Table 7.1). Access dimensions can, on the one hand, provide a useful tool for the authorities to weigh their choice to apply one medium rather than another to reach targeted stakeholders within urban planning problems. On the other hand, the framework can be used as an a posteriori review (with or without the participants) of the interactive session(s) that eventually take place, helping to improve the overall approach. In this framework, each access dimension is examined through a participatory approach lens.

Access dimensions [ab]	Definition [ab]	Discrete scale: levels [1 - 5] [c]
Accessibility	Location	
Availability	Supply and demand	
Adequacy	Organization	
Affordability	Financial and incidental costs	
Acceptability	Consumer perception	
Awareness	Communication and information	

[a] *Penchansky and Thomas 1981* [b] *Saurman 2016* [c] *Introduced in this paper*

Table 7.1. *Scaled access dimensions present in the literature*

7.6.1. Access Dimensions for Interactive Sessions

To characterize the dimensions, we outline each of them into five levels; the upper and lower boundaries of the levels will be labeled and illustrated in this section. Being context-specific, the definition of the dimensions within the framework is broad. Their estimation should be adapted to the situation by considering the targeted public as well as cultural, technological, and political factors. In addition to the framework's resilience over specific contexts, the access dimensions assessment should also be considered through a multi-perspective approach, where age segments should be evaluated, notably if the targeted public is varying. A younger and an elderly population would indeed have contrasted affinity to a particular type of medium (e.g., digital vs. non-digital).

Accessibility refers to the spatial effort that participants must undertake to reach the location of an interactive session. Four aspects determine this effort: (1) facilities, their presence or absence (parking spaces, transportation network); (2) distance (in kilometers, number of transits); (3) time, the duration of the journey (minutes, traffic jam, weather conditions); and (4) costs (financial, gas, parking, or transport tickets). The effort is weighted relatively low in the context of digital participation. The accessibility dimension has been defined from unreachable (level 1, the participant is not able to attend the session because the spatial effort is too significant) to immediate (level 5, the citizen can participate from any location via the use of a smartphone). An example of an average accessibility level in a typical Western European city would be a central location, such as downtown, which is easy to reach by public transportation and has convenient car parking.

Availability encompasses vacant seats for the public. These seats should not be regarded as an absolute number but as the mobilization of the targeted public. According to the medium, this aspect is limited by physical attributes such as the room size, the number of facilitators, etc., or digital characteristics such as server uptime, traffic surges, latency, etc. This criterion has been delimited from being closed (level 1, no citizen can participate, for instance, an in-camera session with experts and elected representatives) to being unrestricted (level 5, the full targeted public can contribute without any restrictions, such as technical, social, financial or personal). An average availability should be considered as gathering a sufficient number of stakeholder representatives to mobilize a range of opinions or ideas from groups composing the targeted public (opposing and supporting).

Adequacy corresponds to matching the selected public to the interactive sessions, according to three concurrent aspects. The first aspect is matching the stakeholders' schedules to the timing of the interactive session. This aspect attempts to determine when a session takes place (part of the day), for how many hours, and with how many occurrences compared to the stakeholders' readiness. The second aspect is the fitness of the scope of the interactive session and its suitability to the citizens' interests and concerns. The third aspect is the participant's ability to participate (knowledge of participatory customs, willingness to speak in front of others, and skills to operate a specific tool). The adequacy aspect ranges from ignored (level 1, an interactive session paired with its selected medium occurs without considering the public's idiosyncrasies) to optimized (level 5, the participation is shaped for the stakeholders). Average adequacy is designed to widen the scope of the involvement, with longer opening hours, shorter sessions, and acutely selected issues.

Affordability is the specific financial costs a citizen must incur to participate. The economic aspect is established using the cost of the session (occasionally used to reach a highly motivated population), combined with the organizational cost (i.e., childcare), specific material cost (i.e., virtual reality headset), or compensation (if applicable). The affordability factor ranges from expensive (level 1, an individual must pay a cost to participate, such as entry fee, materials, etc.) to being rewarded (level 5, the public is compensated for participating, for instance, financially, by goods, raffle, etc.). Average affordability would be when the financial cost to participate (transportation, material, fees, etc.) is balanced with the rewards (e.g., snacks and refreshments, reimbursed expenses, etc.); the participatory session is therefore economically even.

Acceptability characterizes the attitude that the targeted public has toward the participatory approach and, by extension, toward the medium. This aspect is established on participants' social and cultural values. Its evaluation is, therefore, highly versatile. Several factors impact the acceptability, such as disadvantaged neighborhoods (regarding the interactive session's location), presence of specific individuals (other participants or local representatives), selected medium for the session, personal interest to participate (ideological engagement, political affiliation, geographical proximity to the project), and the confidence towards authorities (expected results, the likelihood of participant's inputs being considered, transparency, etc.). The acceptability dimension ranges from cautious (level 1, citizens do not participate out of skepticism induced by concerns about the session or separation between the targeted public values and the session, including participatory washing, legitimacy, medium, and participants) to trusted (level 5, citizens eagerly participate because features of the medium (e.g., instant feedback) make it easier for the public to participate and comply with the session, inducing trust, respect, motivation, etc.).

Awareness varies according to the authorities' communication strategy. A public notice in a few lines on the municipal website compared to a massive presence on social media will not have the same impact on stakeholder groups. The communication strategy depends on the socio-demographic characteristics of the public targeted by the session. Awareness can be raised by resistance groups using their communication channels. Furthermore, the strategy strongly affects the acceptability dimension where information about the approach's philosophy can be broadcasted, such as the selected medium, the methods for analyzing the results, the scope of the interactive session, the session's rules, feedback frequency, the aspects subject to negotiation, and the integration of participants' inputs in the approach (and the urban project). The awareness factor ranges from being ignorant (level 1, no communication about the process is publicized to the broad public) to being conscious (level 5, a vast communication about the procedure is conducted and combined with an effort of mindful feedback and transparency, also including a co-construction approach of the process and the communication strategies with selected identified participants).

7.6.2. Attractiveness—A Meaningful Dimension of Access

The six previous dimensions of access are described from a citizen/medium relation. These dimensions are also defined in the literature from the perspective of participants' abilities (Levesque et al., 2013). Five abilities are categorized and bound to these dimensions of access: (1) the ability to reach, which involves self-mobility, is linked to the aspects of accessibility and availability; (2) the ability to pay, which regards the economic situation of the participant, is related to affordability; (3) the ability to seek is associated with acceptability and refers to personal freedom to select and adhere to the approach; (4) the ability to perceive is connected to awareness, and implies building intelligence and understanding regarding the interactive session; (5) the ability to engage, which fosters the opportunity to participate and the commitment to the approach, is coupled with adequacy. However, we argue that the dimension of adequacy does not entirely fulfill the ability to engage. Indeed, an adequacy that is optimized (in terms of timing, scope, and specific skills) does not ultimately result in the participation of the individual targeted by the authorities Concerns about user-friendliness and the appeal of the medium need to be taken into account. Therefore, we suggest translating these considerations into a seventh dimension of access that plays a vital role in the engagement of individuals, who are not only convinced by the project and the approach. This new dimension is the attractiveness of the interactive session, and, by extension, the attractiveness of the selected medium (Table 7.2).

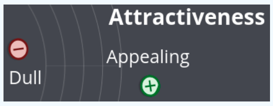
Access dimension	Definition	Discrete scale: levels [1 - 5]
Attractiveness	Effort	

Table 7.2. *New scaled access dimension introduced in this paper*

Attractiveness is determined by dynamics of self-selection (Fung, 2015) and the willingness to participate (Tokarchuk et al., 2012); both are strongly related to the motivation of the participants to commit themselves to contribute to the session. Their motivations, whether intrinsic (altruism, fulfillment, enjoyment) or extrinsic (community, ego enhancement, future return) (Lotfian et al., 2020), can be enhanced by an adequate implementation of the selected medium. Moreover, the perceived effort a targeted public has to invest to attend an interactive session also affects the attractiveness. This aspect can be translated as the entry cost of a session, i.e., the effort required from a stakeholder to participate, in terms of cognitive burden. This aspect is broken down into diverse factors: (1) the depth of exchanges (simple two-way interaction with a medium vs. full immersion with several individuals); and (2) the necessity to learn how to operate a specific tool (e.g., technology, methodology, rules, etc.). Several methods can be taken into account to increase the attractiveness, such as gamification elements (virtual or real), guerrilla participation (a term borrowed from UX design: guerrilla testing), user-friendliness, and public acknowledgment. This dimension contributes to balancing the presence of individuals convinced by the approach (for or against an urban issue), who will always take part in the interactive session, by broadening the range of opinions. The attractiveness factor is classified from being dull (level 1) to being appealing (level 5), according to the targeted public.

7.7. Contextualization of the Access Evaluation

Framework

This section illustrates the use of the access framework in the context of two real case scenarios. The two examples presented hereafter depict, on the one hand, the evaluation of medium alternatives to select the most suitable medium for an interactive session, and on the other hand, the a posteriori evaluation of the participants' access following a specific interactive session.

7.7.1. Illustrative Case: Master Plan Revision of a Swiss Municipality, Anterior Access Analysis of Medium Alternatives

This project has been selected due to the direct involvement of the authors. The authors offered a proposal of collaboration to reply to a tender issued by the municipality. In that context, several discussions were conducted with the municipal officials resulting in the implementation of a proof of concept. The proposal of collaboration was ultimately unsuccessful. However, based on knowledge built during the exchange sessions and the prototype's development, this urban project has been selected to be used as an illustrative case.

7.7.1.1. Project description

Revising a city's Master Plan (MP) is a significant step in the development of an urban place. The MP has the objective to define areas to be built, conserved, or reconsidered during the future evolution of the city. This revision has two main challenges. First, all citizens are concerned, because the MP affects the entire space of the city; therefore, depending on the size of the municipality, the involvement of the population can be costly. Second, the elaboration of the MP is highly technical, which makes it arduous to include the average citizens. In this illustration, the Swiss city has a population of around 150,000 inhabitants. This Swiss city favored establishing a horizon 2030 'plan-guide' based on citizens' inputs to meet these challenges. The 'plan-guide' can be used as a valuable input to the MP revision, while being more flexible and less technical than the latter. This choice made by the municipal authorities is built upon nearly five years of experience in participatory approaches for urban issues. Indeed, this Swiss city started to regularly involve its citizens in urban problems following a massive project failure due to the population's non-engagement. The interactive session, as defined by the municipality, is intended to collect citizens' opinions about places that the public likes or dislikes within the city.

7.7.1.2. Description of medium alternatives

In this framework for analyzing the access dimensions, three alternatives for collecting citizen feedback were discussed in depth during the meetings and partly planned by the authorities: (1) several transect walks; (2) an online survey; and (3) an online 3D platform. The 3D platform was the prototype put forth by the authors, and the online survey combined with the transect walks were the mediums ultimately adopted by the municipality. These medium alternatives are presented in Figure 7.2 from the perspective of interactions between actors.

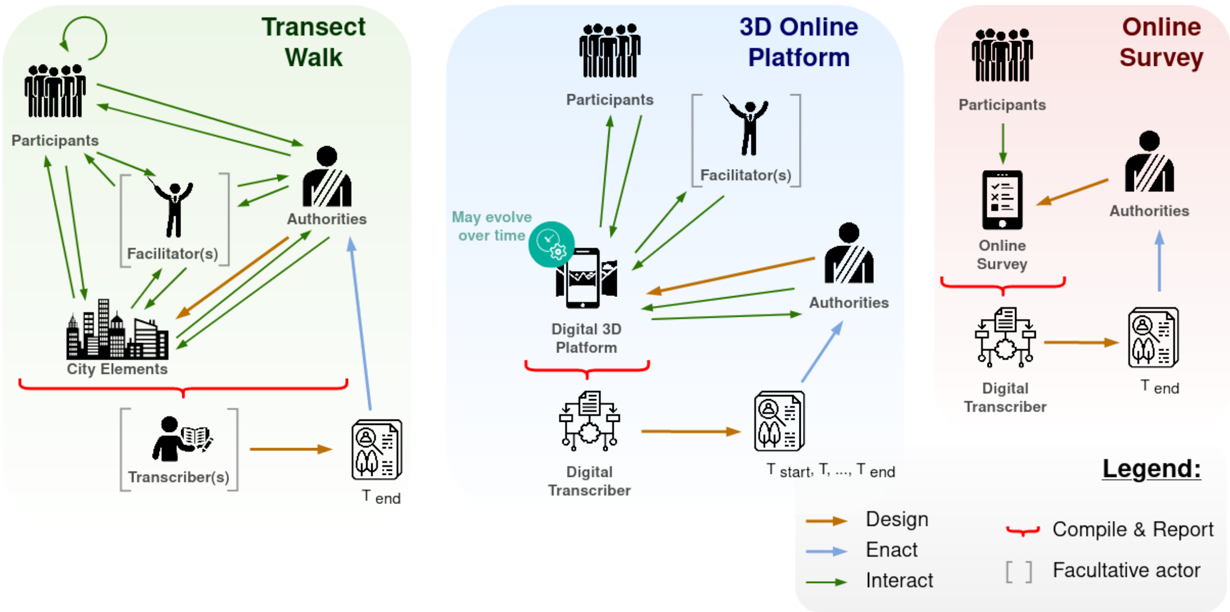


Figure 7.2*. Schema from an actors' interactions perspective of the three options (Transect walk, 3D online platform, and online survey) considered for this urban problem.*

Figure 7.2 portrays four roles engaged in these specific medium alternatives: Participants, Facilitator, Authorities, and Transcriber. The Participants represent the public affected or concerned by one urban project, and who attend the interactive session. The Facilitator often hired by the authorities or the session organizers, moderates and guides the participation. The Authorities are the local state entity that initiates the urban project; during a session, the authorities can be represented by a municipality deputy, a project manager, a decision maker, or even an expert. Their responsibilities can include taking part in the design process of the session, and additionally answering citizens' concerns, appeasing the public with their presence, and sometimes assuming the role of the facilitator. The Transcriber (human or digital) symbolizes the data collection and the post-processing of all the information to report precise and neutral results of the session.

The mediums depicted in Figure 7.2 are described hereafter as conceptualized during the meetings between the local officials of the Swiss city and the authors:

Transect walks. Citizens interact simultaneously with each other, the authorities, and the facilitator (green arrows) during a walk within a neighborhood. Discussions are stimulated using elements encountered during the pathway. A mindful transcriber must gather information exchanged by actors to produce a report highlighting the main topics addressed. The density of data to be collected is challenging, as the participants do not monitor and edit their thoughts as in a written exercise, and several discussions may happen at the same time. Moreover, the reporting (of arguments, emotions, agreements, etc.) at the end of the session could misrepresent part of the stakeholders' debate (misunderstanding of the statements, omissions, emotional writing). The transect walks would occur on weekday evenings (starting time between 4 p.m. and 6 p.m., never the same day) for two hours. The starting and ending point locations would be different. Registration would be mandatory with the unlimited number of participants. Minimal information would be shared about the transect walks (distance, itinerary, topics).

Online 3D platform. All the stakeholders' interactions are centralized, i.e., citizens interact with other citizens, facilitators, and authorities through the platform. It could be accessed by the participants over a week, a month, or more. Synchronous and asynchronous inputs by stakeholders would promote animated debates. Furthermore, the 3D scene that would be broadcasted, could evolve on-the-fly according to the public's insights (and authorities' readiness to make changes). In this medium, a digital script (i.e., the transcriber) would collect all data and produce automated indicators in real-time with the current session state, such as a dashboard of the participation status. Collecting raw data from the platform would prevent bias in the final report (e.g., the complete information can be gathered, no emotional influence, non-subjective interpretation, etc.) (Marzouki et al., 2019). Along with this data, an overview report would be made available to the citizens. The prototype developed expressly for the interactive session aimed to assist stakeholders in locating points of interest in the city (the type of element, frequency of use, opinion). A comment section was made to promote free discussions around these locations. The creation of an account would not be mandatory to participate, yet strongly encouraged.

Online survey. The stakeholders' interactions are simplified. The survey is outlined by the authorities and completed by the participants. This medium enables only one-way interaction. Therefore, the complexity is lessened, i.e., the citizens must follow an URL link and answer the different questions. The survey could be online over several weeks, defined in advance by the authorities. Participants' replies would be administered remotely and automatically. A 3rd party survey service would be used. A dozen questions were sketched, including socio-demographic information collection.

7.7.1.3. Access evaluation of medium alternatives

This hypothetical evaluation of medium alternatives illustrates how this framework should be applied anterior of the participatory approach to determine the most appropriate medium according to the context, but also to the segment of the population. The targeted population for this urban project was the entire population of the city. No restrictions were put on the appropriate stakeholders' socio-demographic characteristics. The authorities aimed to gather maximum information. Conducting participatory urban projects is not new in Switzerland. The population is thus used to participating or giving an opinion. Usually, an extensive communication campaign is conducted by the municipalities, and various channels are employed, such as social media, newspapers (digital and physical), a dedicated section on the city website, advertising panels, etc. The interactive session as designed by the authorities was intended to reach the entire population, all citizens having various socio-demographic traits, backgrounds, or situations. Therefore, assessing the access dimensions fluctuates, and levels are depicted within a range of minimal and maximal value (Figure 7.3). Indeed, the elderly's attitudes towards sessions planned on weekday evenings may contrast to those of people with jobs and family responsibilities. The argumentation of Figure 7.3 is based on Section 7.6 and detailed in Table 7.3.

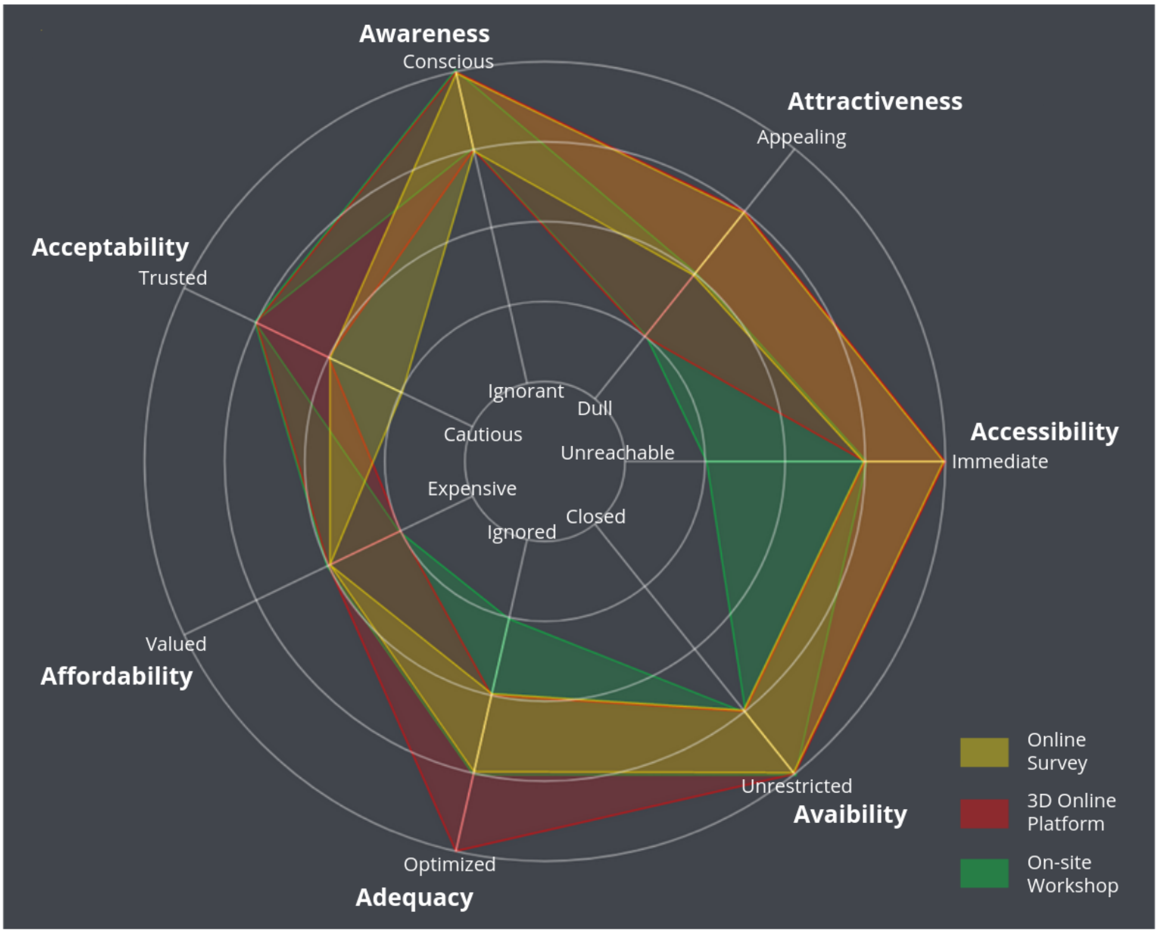


***Figure 7.3**. Dimensions estimation for the three alternatives studied for this urban planning problem*

The ability of the stakeholders to reach the interactive session is relatively high and met for the three mediums. The aspect of accessibility for the transect walks oscillates extensively according to the focused district. Each neighborhood has different amenities which increase or decrease the score of this dimension. In addition, a resident who wants to attend a transect walk in their district and another one downtown will be strongly favored. The survey and the 3D platform benefit from being online, i.e., reachable at anytime from anywhere. They thus empower the participants with an effective ability to reach.

All districts of the city are considered in the MP revision, and the population is accustomed to participating. This context supports acceptability; however, each medium has its specificity. This aspect is deemed high for the transect walks due to their setup: the possibility to address concerns to the authorities without an intermediary. Regarding the online survey, anonymity is beneficial, allowing self-expression more openly without judgment from others. Nevertheless, the impersonal configuration of the survey demonstrates an aloofness that could be interpreted by the citizens as a disregard of the medium by the authorities. The 3D platform stands in the middle, where written elements saved and retrievable by anyone can be seen as an obstacle only by a part of the population (not accustomed to social media).

Access dimensions		Evaluation criteria (• neutral, + positive, - negative)
Accessibility	*Transect Walks*	- need to travel to the location of the participatory session - the starting point and ending location are different • transportation facilities depend on the transect location
	3D platform	+ from anywhere with a smartphone or from home with a computer - not all smartphones can render 3D graphics (a computer is recommended)
	Survey	+ from anywhere with a smartphone or from home with a computer
Availability	*Transect Walks*	+ no limitation of participants (within an organizational limit)
	3D platform	+ no limitation in the number of participants - prototype, users may encounter a bug or downtime
	Survey	+ no limitation in the number of participants + use of a 3rd party survey service, reduce the risk of downtime
Adequacy	*Transect Walks*	- thematics unknown in advance, chosen by the authorities - 17 sessions of 2 hours on weekdays in the evening (sometimes starting at 4 pm)
	3D platform	+ platform accessible 24/7 via an internet connection + free choice to select the point of interest • 3D navigation skills
	Survey	+ platform accessible 24/7 via an internet connection - non-flexible questions
Affordability	*Transect Walks*	• event on a weekday may induce organizational fees • no entrance fee
	3D platform	- 3D graphics rendering requires a performant smartphone or computer • no entrance fee
	Survey	• no entrance fee
Acceptability	*Transect Walks*	+ citizens accustomed to the procedures and to participating + proximity of the authorities
	3D platform	+ citizens accustomed to the procedures and to participating • written record that can be consulted by all • anonymity if not registered
	Survey	+ citizens accustomed to the procedures and to participating + anonymity - impersonal - no opportunity to get more information on the consideration of the results
Awareness	*Transect Walks*	+ massive communication campaign + various channels are exploited
	3D platform	+ massive communication campaign + various channels are exploited
	Survey	+ massive communication campaign + various channels are exploited

Attractiveness	*Transect Walks*	- outside, need to walk a couple of kilometers - online registration is needed - complexity of the actors' exchanges
	3D platform	+ wow-effect of the 3D representation - non-familiarity with the medium • one-way user interaction • no mandatory registration but strongly encouraged
	Survey	+ no registration + familiarity with the medium - simple survey

Table 7.3. *Side-by-side comparison of medium alternatives facing access dimensions, argumentative table.*

Lastly, the ability of the population to engage differs according to the medium. The online 3D platform encompasses the most comprehensive range. As an online medium, citizens can participate when it suits them best. However, participants should be minimally proficient with 3D navigation, even if a small tutorial would be recommended before pinpointing locations. The attractivity dimension also differs depending on the participant. On the one hand, the 3D representations can be engaging by their novelty (especially for the youth), but on the other hand, repellent because of the non-familiarity of this type of portrayal (especially for the elderly). Transect walks are evaluated average-low according to adequacy and attractivity. First, several events would be organized, some starting at 4 p.m., which is inconvenient for daily workers. This medium setting, outside along a predefined pathway, is enjoyable, although quickly troublesome for people with reduced mobility (walk a couple of kilometers, no sitting for 2 h). The online survey achieves an average ability to engage. Despite being a medium well-known by the citizens, the questionnaire does not allow much flexibility in the thematic and the way of conducting the interactive session.

From this a posteriori evaluation of the dimensions of access, the authorities could decide to select a (or a combination of) medium(s) to enhance the mobilization of the targeted public. The medium that has the best overall score should be the preferred alternative, but according to other perspectives, such as costs or risks, another alternative can be selected. The criteria collected during the evaluation can be used to address any dimension that seems insufficient.

7.7.1.4. Outcome: selection of the medium

The municipality representatives eventually adopted a participatory approach combining two of the mediums presented before: online survey followed by transect walks. The synergy between online and offline involvement promotes broader participation, where some citizens reluctant towards digital technology are willing to participate in a more traditional setup and vice versa. When we combine the evaluation of the online survey and the transect walks, we observe an expansion of some access dimensions, such as accessibility that now ranges from 2 to 5, or acceptability which scores 2–3 and 5. This expansion helps to counterbalance the limits of one medium with the benefits conveyed by the other. However, we can also notice that the overall lowest evaluation of the combination of these mediums leads to a decrease in the level of certain access dimensions, compared to the level of one or the other medium alone. Therefore, engaging the targeted public over the two mediums seems ambitious, but the prospect of committing individuals to one or the other medium appears reasonable. As explained throughout the description of the framework, the socio-demographic characteristics of each individual will affect their perception of the access dimensions. This variability should be mindfully considered during the evaluation of the dimensions in order to adequately mobilize the targeted public. If used effectively, this framework could assist local officials to design the right interactive session by increasing the opportunity of collecting accurate information from the local experts and limiting the risks of conducting a flawed participatory approach. Nevertheless, the practice of this framework is not a substitute for the monitoring of the participants' representativeness. If the socio-demographic groups attending the sessions are imbalanced, the local officials must respond by expanding the mediums, i.e., increasing the access, to engage the citizen groups that are missing.

7.7.2. Illustrative Case: ZImeysaver, a Posteriori Access Evaluation

This project has been selected due to its joint conduction between the Canton of Geneva and the institute InsIT of the HEIG-VD (institution of the authors). The documents used for this study are the deliverables produced as part of the participatory approach undertaken for this project (ZIMEYSAVER, 2017).

7.7.2.1. Project description

The ZImeysaver is an industrial area that spreads over three municipalities: Vernier, Meyrin, and Satigny in the Canton of Geneva, Switzerland. The central part of the project is to create a new road section to connect a proximate highway with the ZImeysaver area. The goal is to improve the connectivity of the project site and to absorb the increased circulation caused by the future development of the industrial zone. The potential creation of 10,000 new jobs is projected for 2030. The concerned population is estimated at nearly 65,000 inhabitants (the combined population of the three cities), plus day workers. The local stakeholders publicized a strong opposition to the project. In this context, a participatory approach was set up to disarm the situation. The process was divided into three steps: a diagnosis, two interactive sessions (in the form of on-site workshops), and an informative session. Our a posteriori evaluation of the access will focus on the two interactive sessions.

7.7.2.2. Interactive sessions' description

Two interactive sessions took place on 8 February and on 1 March 2018 from 6 p.m. to 9 p.m. The sessions were in line with a consultative level of participation (Chassin et al., 2019) and adopted an on-site workshop as a medium of interaction. The red dot in Figure 7.4 highlights the location of the meetings. This position is adjacent to the ZImeysaver and is located within the most populated of the three affected municipalities. A train station connected to the two other cities is within walking distance (10 min). A bus stop is also close to the meeting point (5 min). Around 30 parking spaces are available outside the event building.

***Figure 7.4**. Contextualization of the interactive sessions designed for the ZImeysaver*

Each interactive session could host a maximum of 60 citizens (five round tables of 12 participants max). A round table was constituted of a dozen participants, a facilitator (project managers, organizers), and a transcriber. The agenda was directed as described hereafter: welcoming of the participants, speech about the organization of the session, two times 40 min of exchanges about a specific issue (with a break between the discussions), immediate feedback done by the note-takers, closing speech, offering of snacks and refreshments. The issues discussed had been selected according to the citizens' concerns revealed during the diagnosis phase. The first interactive session focused on mobility and its impacts, while the second was axed on agriculture, landscape, and economy. To participate, citizens had to register for the session and select their preferred topics in advance. The communication strategy employed by the organizers was composed of a flyer distributed in all mailboxes of the citizens living in the municipalities and a post published on the Canton website (the Canton was scarcely active on social networks). The targeted public of the interactive session were ardent opponents; a few of them were already involved during the diagnosis phase. The two interactive sessions gathered 65 participants (46 for the first workshop and 19 for the second). These participants were mostly inhabitants and farmers affected by the project.

7.7.2.3. Access evaluation

The a posteriori access estimation demonstrated herein highlights average-high access for these two interactive sessions (Figure 7.5). The goal of these sessions was to restore dialogue between the ardent opponents of the project and the authorities and to find a middle ground. Only 65 participants out of 120 (maximum capacity) attended the session; however, nearly all appropriate stakeholders came. The levels depicted in Figure 7.5 have been characterized according to the definition of each dimension described in Section 7.7, and their argumentation is demonstrated in Table 7.4.

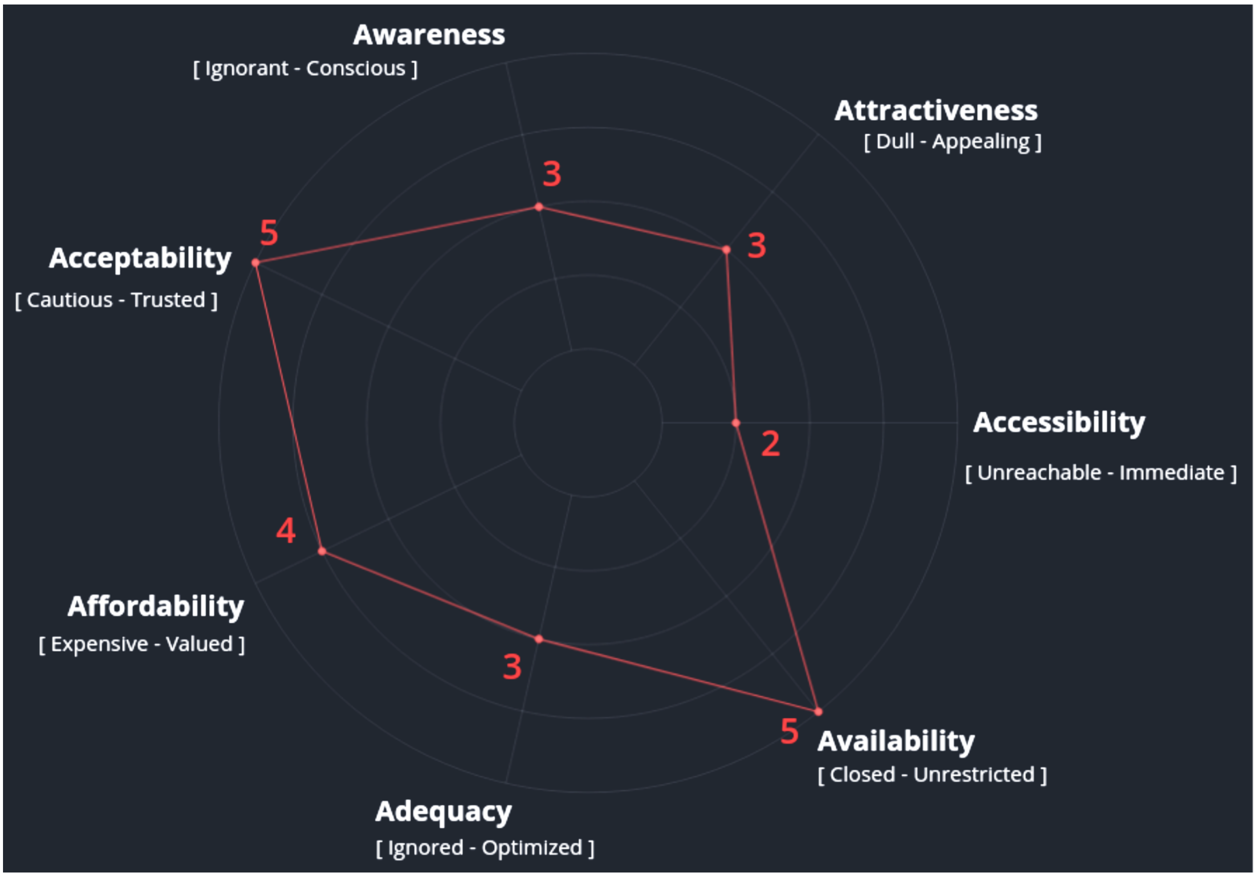


Figure 7.5. *Dimensions estimation for the on-site workshop medium studied for the ZImeysaver project.*

The lowest scaled dimension is accessibility. The second session indeed suffered from unfavorable weather conditions (snow), increasing the time of transportation. The organizers highlighted this argument as the main reason for the drop in attendance between the two sessions. A way to counterbalance this limited score would have been to increase the targeted public's ability to reach the interactive session by offering a new way to interact during the session remotely (videoconference) or after the session (mail post, email, online survey).

Regarding the average level of adequacy and attractiveness, the ability to engage the participants could have been enhanced. The choice of the on-site workshop medium limits the moment of engagement for a few hours on a specific day. Therefore, when a non-controllable factor drops the dimension of accessibility, the citizens can only sparsely participate. The public's profiles were individuals mostly over 50, some of them accustomed to the public arena (local politicians). The on-site medium with its formal settings fits their portraits (used to participatory codes, hypothetically more able to be free on evenings, highly motivated). However, the online mandatory additional step to register for the event adds a boundary to moderately motivated citizens.

Access dimensions	Evaluation Criteria
Accessibility	- must travel to the location of the participatory session - snowy weather for the event on 1 March • well-connected to the public transportation network • 30 parking spaces
Availability	+ did not reach the maximum capacity • 5 tables of a maximum of 12 participants
Adequacy	+ topic selected according to citizens' concerns - 2 sessions of 3 hours on weekdays in the evening
Affordability	+ snacks and refreshments offered • no entrance fee • event on a weekday may induce organizational fees (childcare, …)
Acceptability	+ authorities' open attitude: consultation + citizens accustomed to the procedures and to participating + proximity of the experts and project managers • context of strong opposition towards the project
Awareness	+ flyer distributed to all households concerned + some participants are already involved (word-of-mouth) - no social network communication
Attractiveness	- online registration is needed • formal setting of the on-site workshop • full immersion increases the cognitive load

Table 7.4. *Argumentative table of the access dimensions' estimation*

The approach designed by the organizers fulfilled its role in mobilizing a handful of ardent opponents. However, the drop in attendance between the two sessions shows that some individuals (including probably a few opponents), who were interested in participating, could not take part in both sessions. Analyzing the criteria identified in the evaluation could help to understand this drop (in this case it was poor weather conditions) and to design potential solutions that could address future challenges.

7.7.2.4. Including participants' insights within the access evaluation framework

The opinions of participants on the conditions of access to the interactive session can also be considered through this framework. Their assessment compared with the results of the previous section intend to create another perspective on the access dimensions (closer to the citizens). Therefore, experts' and participants' views can be compared to highlight uniformities and dissimilarities. However, asking the participants to fulfill the raw access dimension framework would be too challenging. Therefore, the framework's complexity should be reduced. For this purpose, the authors argue for designing a survey where participants' socio-demographic characteristics and access dimensions (split into small queries) can be ascertained through specific questions. Each dimension could be symbolized by a thematic constituent of a few questions. The result would be a combination of the users' answers.

7.8. Access Evaluation Framework Implications for Participatory Approaches

The legal obligation to use participatory approaches in urban planning projects introduced by the SPAs encourages the authorities to reconsider their methods of governance. Facing this radical change, the local officials demonstrate hesitation based on concerns about their decision-making power (being the accountable entity with legal competency) or past negative experiences. This progressive institutionalization leaves the authorities to the design of these involvement processes without the expertise to conduct these types of approaches. The selection of a medium, as an instrument for social interaction and a transcriber of potentially antagonistic knowledge (between the technical knowledge guarantors on the one hand, and the local knowledge guarantors, that are experiencing the place on the other hand) is one of the critical steps to address for the design of these approaches. If mishandled, the mobilization of the targeted public to an interactive session can be missed, weakening the legitimacy of the solution provided by the entire participatory approach. The local authorities must carefully define the conditions of the access of the public to their participatory approach, in order to reduce, firstly, the power dynamics that occurs in a group of participants, secondly, the over-representation of socio-demographic groups. Hence, the authorities should identify the targeted public and the means to adequately mobilize it through a medium. However, while these two steps strongly limit the power politics within participants by improving the heterogeneity of the group, they do not guarantee the absence of power dynamics (Hopkins, 2010). The access evaluation framework developed in this study aspires to support the authorities in their choice of medium by evaluating dimensions around the conditions of access of the targeted public. Through the fulfilling of the seven dimensions, the local officials can estimate the medium that is most adapted to the targeted stakeholders of the session, including identifying benefits, opportunities, as well as disadvantages introduced by each studied alternative. Via this estimation, the authorities can efficiently arrange their expectations about the deliverables for the interactive session. Moreover, this framework applied as an evaluation tool following an interactive session can enhance authorities' understanding of the citizens' attitude towards a particular medium. This framework, therefore, aspires to help local officials to build confidence in their aptitude to design such interactive sessions by offering them the tools to succeed.

The harmonization of the territory's economic development with the image of this territory as a "living place" to be protected (Dechézelles & Olive, 2016) is based on numerous parameters. These parameters determine the selection of a medium that fits the targeted public and the overall approach, such as: level of participation, level of interaction, purpose process of the stage, reach, scalability, participant selection, participant skills, cultural applicability, costs, interaction quality and depth, and required labor and expertise (Münster et al., 2017). These factors, firstly described for online mediums, are also valid for on-site participation. This large set of factors ranging from the user's abilities to the project's specificities, and passing by economic constraints, directly impact the selection of a medium. Indeed, participatory approaches are highly dependent on the context in which the medium is inscribed (users, temporalities, scales, policies) (Chassin et al., 2019). A holistic estimation should, therefore, be considered in the selection of the medium, the evaluation framework offering only one concern of the issue.

Each medium offers benefits and drawbacks, mainly when digital technologies are involved (Aubert et al., 2020). Mediums' disparities are illustrated in this study in Figure 7.3. Some individuals from the targeted public could be more attracted to one medium than another because of personal or socio-demographic inclinations. Furthermore, each medium's assets and limits are generally complementary. For instance, an on-site participation asset brings experts into the discussion, where their relationship with the public is straightforward, without go-betweens. Their presence around the table consolidates the public's perception of the authorities' will to answer citizens' apprehensions, resulting in improved trust and commitment from the population. Experts in online participation are often more distant, and it can be laborious for participants to have an answer. One of the reasons is that an expert cannot be connected 24/7. The second is, considering a broader population reached by digital medium, every post cannot find a reply due to their large number. The improvement of trust and commitment described previously is, therefore, limited. A medium limit can be strengthened by another medium and vice versa. Based on this consideration, an appropriate combination of mediums (digital or traditional) should improve the overall participation approach and the targeted public reachability (Chassin et al., 2019; Rowe & Frewer, 2000; Žlender et al., 2021).

7.9. Conclusions

The gradual institutionalization of participatory approaches encourages the incorporation of local stakeholders in the decision-making arena. This involvement is challenging for local authorities that should, on the one hand, identify a targeted public for the scope of an interactive session, and on the other hand, engage these individuals through a specific medium. These challenges can quickly discourage the local officials that are lacking expertise and tools to make the right choice. This paper aims to bridge some of this gap by introducing an access evaluation framework articulated around the notion of access. Seven dimensions are presented from a participatory perspective: accessibility, availability, adequacy, affordability, acceptability, awareness, and attractiveness. This new tool aspires to support the authorities during their selection of the best suited medium alternative to reach a targeted public. Moreover, this framework, if adopted after an interactive session, can stimulate a continuous improvement process. The organization of urban participatory approaches is certainly not limited to public access, therefore, the use of this tool should be included in a holistic evaluation, which considers other aspects, such as costs or risks.

Accelerated by the SARS-CoV2 pandemic, the digital transformation of participatory approaches introduces considerable stakes for the public. The promise of a genuine and broadened participation seems appealing; however, regarding a targeted public not proficient with digital technology, this potential could turn sour. Therefore, identifying the appropriate individuals supported by the local authorities is a crucial step in the participatory process, followed by the equally important selection of the right medium (enhanced by the access evaluation framework). A skillful practice of these two steps increases the likelihood of giving everyone from the targeted public equal access to the participatory processes. This could support the concerned citizens in expressing their opinion on urban issues, limiting bias and increasing the fairness of the decision, and ultimately contributing to the success of the participatory approach and the urban project.

URLs

CityPlanner: beta.cityplanneronline.com/site (last accessed on July 9, 2020); NeoCity: neocityview.com (last accessed on July 9, 2020); Open Government Partnership: opengovpartnership.org (last accessed on July 9, 2020).

Acknowledgments

The icons used to build the figures originate from the Noun Project. Figure 8.1: "Cancel Download" and "Start Download" by Ranah Pixel Studio, Place by Hrbon, Puzzle by Jokokerto, Problem by Adrien Coquet, Media by Nithinan Tatah, Communication by Shashank Singh, Puzzle by Visual Language, Puzzle by Akshar Pathak, Settings by Danishicon, Choice by Dong Ik Seo and Team Selection by B Farias. Figure 8.2: Report by Becris, People by Benjamin Harlow, Panoramic Landscape and Music Composer and Online Survey by ProSymbols, Mayor by Laurent Patain, Algorithm by Eucalyp, Writer by Adrien Coquet and City by Mohkamil.

Chapter

8. Paper D: Experiencing Virtual Geographic Environment in Urban 3D Participatory E-planning: A User Perspective

List of abbreviations for the chapter:

VGE: Virtual Geographic Environments
IAP2: International Association of Public Participation
ICT: Information and Communication Technologies
LOD: Level of Detail
VR: Virtual Reality
Col2: LOD 2 + color
Col1: LOD 1 + color
Tex2: LOD 2 + textures
Foc2: LOD 2 + focus

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8.1. Preface

The previous chapters addressed the three main investigations of my Ph.D. thesis: the practices, the participants, and the 3D medium. Answers have indeed been suggested with a better understanding of current 3D participatory practices through the press coverage, a clearer comprehension of the dynamics that encourage participants to take part in a participatory session via the access dimensions, and an enhanced awareness of the complexity in the design of virtual geographic environments with the identification of the challenges related to their implementation. Building knowledge around these topics is crucial to improve urban participatory approaches, however, as explained previously, urban projects and their related participatory approaches are strongly interconnected and impacted by multiple social, political, contextual, financial, technical, and cultural factors. Therefore, the applicability of an increased understanding of the main topics of my research (practices, users, 3D mediums) individually will only be limited. Investigating the interconnection of these topics could enhance the significance of the findings demonstrated by each topic independently. Hence, in this chapter, I focus my lens on the relationship between practices, users, and medium through a user experiment.

Publication and personal contributions

Chassin, T., Ingensand, J., Christophe, S., & Touya, G. (**2022**). Experiencing virtual geographic environment in urban 3D participatory e-planning: A user perspective. Landscape and Urban Planning, 224.
doi: 10.1016/j.landurbplan.2022.104432

Personal contributions: formulation research goals and aims, development and design of methodology, software development; designing web application, analyze and synthesize study data, figures preparation, manuscript writing.

Highlights

- *Fluctuation in experiencing VGE is due to conceptual, cognitive, and portrayal gaps.*
- *The VGE representation impacts mostly the time needed by users to complete a task.*
- *Spatial abilities strongly affect users' performance while manipulating a VGE.*
- *Current participatory setups using 3D appear to hinder the potential of VGE.*
- *The online format adopted in this study was valuable to evaluate users' performance.*

8.2. Abstract

The adoption of technology in urban participatory planning with tools such as Virtual Geographic Environments (VGE) promises a broader engagement of urban dwellers, which should ultimately lead to the creation of better cities. However, the authorities and urban experts show hesitancy in endorsing these tools in their practices. Indeed, several parameters must be wisely considered in the design of VGE; if misjudged, their impact could be damaging for the participatory approach and the related urban project. The objective of this study is to engage participants (N = 107) with common tasks conducted in participatory sessions, in order to evaluate the users' performance when manipulating a VGE. We aimed at assessing three crucial parameters: (1) the VGE representation, (2) the participants' idiosyncrasies, and (3) the nature of the VGE format. The results demonstrate that the parameters did not affect the same aspect of users' performance in terms of time, inputs, and correctness. The VGE representation impacts only the time needed to fulfill a task. The participants' idiosyncrasies, namely age, gender and frequency of 3D use also induce an alteration in time, but spatial abilities seem to impact all characteristics of users' performance, including correctness. Lastly, the nature of the VGE format significantly alters the time and correctness of users' interactions. The results of this study highlight concerns about the inadequacies of the current VGE practices in participatory sessions. Moreover, we suggest guidelines to improve the design of VGE, which could enhance urban participatory planning processes, in order to create better cities.

8.3. Introduction

The role of urban dwellers has been acknowledged as crucial in urban planning practices for decades (Arnstein, 1969). Citizens living in their neighborhoods are cultivating a unique local knowledge driven by their experiences, emotions, or, in other words, their everyday life (Corburn, 2003). In the perspective of local urban governance, this intimate expertise is valuable for non-omniscient authorities who have an administrative conception of the same territory. The involvement of dwellers in urban participatory planning can mobilize their local expertise, and thus, leverage several issues in implementing urban projects. An active participation can indeed help to reduce oppositions via the reinforcement of the social acceptability of the project (Wüstenhagen et al., 2007), or help to cultivate a reliable project intelligence among citizens that could lead to the appropriation of the project by the population (Joerin et al., 2009). In this study, active participation is defined as a government-initiated process that engages the population following the *spectrum of public participation* described by the International Association for Public Participation (IAP2, 2014). This spectrum describes five levels: inform, consult, involve, collaborate, empower. This time-bound involvement can be conducted in-person or online, and intends to complete specific tasks related to the spectrum, such as providing feedback on certain aspects of the urban project, contributing to the project by suggesting alternatives, etc.

However, engaging the population in participatory sessions is not trivial. Each selected medium used to reach the population has its benefits and drawbacks, which leads to mobilizing only a limited part of the potential participants (Chassin, Cherqui, et al., 2021). The inclusivity of a participatory session, which means reaching a targeted population, cannot, therefore, be accomplished by adopting only one medium, but by combining different participatory tools that are selected according to the preferences of the individuals constituting the targeted population. The meaning of inclusivity for a participatory session and its medium differs according to its context of application (e.g., Eastern vs. Western countries) (Zhang et al., 2019); hence, numerous factors should also be considered to reach inclusivity such as cultural, political, economical, contextual or societal factors.

New participatory mediums are developed to bridge these hindrances and Information and Communication Technologies (ICT) solutions are often favored (Babelon et al., 2021; Gün et al., 2020; Haklay et al., 2018; Smith & Martín, 2021). Although the use of such tools has yet to be consolidated in planning practices (Afzalan & Muller, 2018), citizens are increasingly using ICT in their daily lives. The ubiquitous use of smartphones and (social) web applications bring the population to cultivate their skills in using digital technology (Ertiö, 2015), i.e., improving their ICT literacy. These digital skills are frequently the focus of concern in the adoption of ICT technologies within participatory practices (van Deursen & van Dijk, 2011), besides other factors such as trust, perceived complexity, data security or past positive experiences (Leroux & Pupion, 2022).

One of the most striking examples of digital literacy development is the Virtual Geographic Environments (VGE) (Lin & Gong, 2001), which are the core of this study. Since 2005 and the birth of Google Earth, the consumption of VGE has been thriving. These 3D representations are currently adopted in a wide variety of sectors (Biljecki et al., 2015), urban planning being one of them. In urban participatory approaches, VGE are a valuable opportunity for the local authorities to better involve the population in planning processes. One of the most compelling benefits of 3D representations is the enhancement of the user's immersion within a hypothetical future. Indeed, these visualizations help users to understand complex aspects of the project (Newell et al., 2021; Smith et al., 2020), which ultimately leads to meaningful contributions from users. This understanding can even be extended to participants not familiar with the surroundings (Onitsuka et al., 2018).

Nevertheless, 3D representations are rarely used outside of exploration studies in urban participatory planning (Gill & Lange, 2015). Skepticism regarding the adoption of VGE in participatory practices could be explained by the complexity of their design and uncertainty around their publication. Several challenges in creating 3D geo-visualizations have yet to be overcome, such as the fusion and visualization of diversified data, or the consideration of the idiosyncrasies of individuals, such as age, gender, and spatial abilities (Çöltekin et al., 2017). In addition, because these representations are materializing hypothetical futures, they have a powerful impact on the conduction of participatory sessions and on the population's perception of the urban project. If misused, the same 3D representations could lead to unexpected outcomes (Jacquinod & Bonaccorsi, 2019). The layout of 3D geo-visualizations conveys a meaning that is interpreted by the viewer (Raaphorst et al., 2017). An inadequate use of its content could, for instance, drive the population to perceive a future reality that does not conform to the built project (or the authorities' idea) (Downes & Lange, 2015), leaving the accountable authorities in a delicate position. The fluid comprehension of VGE, which could cause inadequate results, is articulated around three dimensions: a conceptual gap between the author and the viewers, a cognitive gap between the individuals themselves, and a portrayal gap encompassing the context in which VGE are broadcast, i.e., a 3D snapshot taken at a specific time, with objectives, within a setup and with definite features (Metze, 2020).

This study aims to investigate through a user experiment these three dimensions in order to facilitate the design and the use of VGE in urban participatory planning, and ultimately enhance this practice. This enhancement can be achieved by better describing the fluid comprehension of VGE in order to find solutions to reduce its extent. The next section will describe in more detail these dimensions while introducing research questions specific to each of them. Then, the experimental study will be introduced with its characteristics. The main findings will be illustrated in Section 4 through three metrics articulated around users' understanding, efficiency, and adaptability in the manipulation of distinct VGE. Last, the results will be discussed from a participatory perspective in order to provide guidelines for implementing VGE in urban practices.

8.4. A Conceptual Framework for 3D Participation Platform

8.4.1. The Conceptual Gap: Creator/Viewers

The creator of a VGE (or any visualizations) defines how to symbolize a snapshot of reality through the adopted visual representation Level of Detail, textures, transparency, additional objects, etc.). This process introduces diverse choices, conscious or unconscious, guiding the interpretation of the VGE by the public (Juřík et al., 2016; Koláčný, 1969). In urban planning, the local authorities (or consultancy firms endorsed by the authorities) play this design role. The guidance offered by the VGE, for instance, by facilitating the understanding of the scene via storytelling (Thöny et al., 2018), could drive the participants to produce relevant feedback or, in contrast, noisy contributions. One delicate choice in the design of VGE vividly discussed in the literature is the level of abstraction, which ranges from abstract-based (low Level of Detail, gray level surfaces) to veristic-based (high Level of Detail, photo-realistic textures). On the one hand, veristic representations facilitate self-projection and emotional bonding with the scene, enhancing the sense of place (Appleton & Lovett, 2003; Jaalama et al., 2021; Newell et al., 2021; Sheppard & Cizek, 2009). On the other hand, abstract representations are less cluttered, which reduces the cognitive load and focuses the attention of participants (Judge & Harrie, 2020; Santella & DeCarlo, 2004). Several aspects of the urban projects or the tasks to accomplish could lead the adopted representation to either hinder or enhance the participatory practices (Boér et al., 2013; Chassin et al., 2019; Hayek, 2011). Hybrid representations are also explored to balance the limits introduced by the two level of abstraction alternatives (Brasebin et al., 2016; Lokka et al., 2018; Salter et al., 2009; Semmo et al., 2012). Hence, the local authorities often struggle to select the appropriate type of representation for the design of their approach.

Investigating how viewers interpret VGE-based on their representation is crucial to close the conceptual gap induced by creating 3D geo-visualizations. Building this knowledge will ultimately lead to better decisions in the selection of the representation. Therefore, in this study, we are exploring how the representation of a VGE in terms of Level of Detail and texturing affect users when they perform tasks in an urban participatory session.

8.4.2. The Cognitive Gap: Viewers/Viewers

The adoption of ICT tools within urban practices fosters participation by reaching a wider population (González et al., 2008; Kahila-Tani et al., 2019). VGE as an ICT tool also promotes broader participation. However, the engagement of a multitude of participants also brings wide socio-demographic heterogeneity. Considering that understanding and experiencing VGE differ significantly between individuals (Stanney et al., 1998), this diversity could, in some cases, lead to negative outcomes for the participatory session. Each session has specific objectives and targeted participants, which are defined in advance by the authorities (or their representatives). A medium or representation that is not adequate for certain individuals could lead to irrelevant feedback (i.e., not in line with the objectives of the session), crystallizing opposition (because of misunderstandings), or excluding parts of the targeted individuals (because of a lack of abilities).

Many studies assessed the impact of socio-demographic characteristics on the performance of users related to VGE. Age has been proven to be a determining factor. Seniors are indeed less efficient in conducting cognitive tasks that are intensive (Kessels et al., 2010). Therefore, compared to younger people, they often experience hardship while switching the perspective of the 3D scene (Lokka & Çöltekin, 2020), or while controlling allocentric interactive metaphors, which convey abundant information (Colombo et al., 2017). These two elements are frequently used in VGE. Other socio-demographic characteristics, such as spatial abilities, gender, expertise and education, have also been identified as significant factors in the reduction of 3D performance (Herman, Řezník, et al., 2018; Wolbers & Hegarty, 2010).

Understanding and considering the population idiosyncrasy is central to urban participatory planning when adopting any participatory medium (including VGE). The consideration of socio-demographic characteristics could enhance the fairness and the inclusivity of the approach. Indeed, determining which characteristics of the population affect the interpretation of a VGE could help to design strategies that reduce the cognitive gap between individuals. Hence, this study aims at identifying which interactive aspects of VGE are altered by individual characteristics and how strongly.

8.4.3. The Portrayal Gap: Broadcast Format

The publication of VGE in an urban participatory context compels the local authorities to choose a specific format, ranging from static photo-montage to immersive Virtual Reality (VR), including others, such as video or web applications (see, Chowdhury & Schnabel, 2019; Velarde et al., 2017; Virtanen et al., 2018). These formats are not “created equal” because they have different levels of realism or immersiveness (Çöltekin et al., 2016), which transforms the narratives or the methods of portraying the information included in VGE. The selection of a VGE version (i.e., its format) forces users to undergo a specific experience, which will ultimately affect their perceptions and behaviors. Several studies aim to better understand how users perform on particular tasks with different VGE formats, such as between static and interactive VGE (Herman, Juřík, et al., 2018; Juřík et al., 2020), pseudo 3D (screen-based) and real 3D (stereoscopic-based) (Juřík et al., 2020), and desktop-based and VR-based (Dong, Yang, et al., 2020). We observed various participatory sessions and noted that common practices of 3D geo-visualizations are: (1) static images (photo-montage or architectural design) supported by 2D map documents, and (2) projected videos that participants watch (often once) at the beginning of a session before working with 2D maps. A few interactive VGE that were employed were manipulated by trained operators, leaving the participants as passive users. However, active interaction is a crucial aspect of VGE (Sheppard & Cizek, 2009; Smith & Martín, 2021; Thöny et al., 2018).

The current practice of VGE in urban participatory planning does not seem to consider the benefits of active interaction in their design. We argue that this hindrance weakens the overall participatory approach, inhibiting the participants from sharing relevant opinions, insights, or stories. With this study, we, therefore, analyze how users perform participatory tasks within different contexts of interactivity.

8.5. Methods

To respect the safety restrictions on in-person gatherings introduced by the global COVID-19 pandemic (April 2020), we adopted an online setup to conduct this experimental study. The design of a digital study introduces many challenges that are less critical to address in an on-site setup, such as biases in user representativeness, data correctness, and dropout rate (Zhang, 2000). To limit the latter, we reduced the study to its essentials and emphasized user-friendliness through the simplicity of use, user engagement, and low entry costs. However, the core of the study comprised 20 min of arduous VGE-based tasks that could drive users to exhaustion and discouragement. To keep participants engaged with the study, we introduced gamified elements, such as a personal score, a reduced socio-demographic section (based on a fill-in-the-gaps paragraph written in the first-person), and a badge system (personalized digital reward for the completion of the study).

The study was open to everyone and accessible online via a personal computer. We used several communication channels to reach a wide range of participants. Besides traditional social networks (e.g., Facebook, LinkedIn) activated via personal accounts or specific working groups, we adopted other means such as Reddit (a discussion website), Georezo (a French forum for Geographical Information Science professionals), and a newsletter about topographic sciences. The study took place during the 2020 academic break. We collected 107 completed responses from the participants.

8.5.1. Procedure

The study was only available on personal computers; smartphones were not compatible. This choice accommodated two desired conditions: development time and a quiet environment. On the one hand, implementing a web app that is responsive to any kind of device can be time-consuming. On the other hand, the use of a smartphone induces frequent interruptions by notifications (Mehrotra et al., 2016), or divided attention (Wilmer et al., 2017), which are not suitable for the complexity of the tasks that were needed to be fulfilled. We assumed that the use of a personal computer encourages participants to complete the study in a calmer environment, seated at a desk, and hypothetically, with fewer interruptions. We framed the study procedure in three sections: welcome & training (landing page, terms of use, socio-demographic, tutorial), survey tasks, and feedback & results (comments, score page, acknowledgment, personal feedback). The tutorial aimed to outline the tasks that users had to perform throughout the study. Following the tutorial, participants were invited to start their tasks; the process is depicted in Fig. 8.1. Users were confronted with six batches, and each batch was composed of a set of tasks for a specific representation and metaphor of the VGE (see next section for the details). To complete the study, participants had to achieve 18 tasks in total. In the end, the participant could provide feedback about the study before reaching the last page, where the results were shown, along with some acknowledgments.

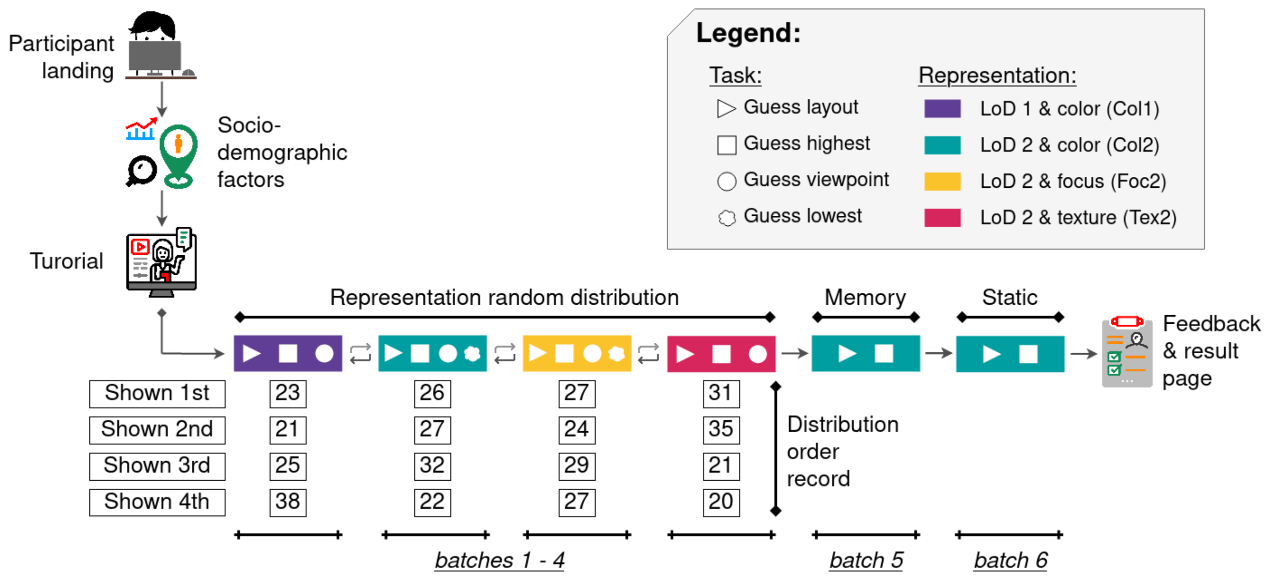

Figure 8.1. *Graphical procedure of the experimental study. The batch order was random for each participant. The number of times a batch is shown in the first, second, third, or fourth position is depicted by the table present in the figure*

8.5.2. Descriptions of the Batches

Several VGE were designed for this study, and each VGE illustrated a reduced city model of 16–19 buildings (the technical details are described in the supplementary materials section, appendix D). Various batches were implemented to address the research questions, four representations were selected in order to assess their impacts on the participants' performance. In addition, three metaphors were implemented to simulate different participatory session setups. Lastly, four tasks were designed, which mimicked participatory activities or concerns that we observed in Switzerland. The batches were designed to evaluate the performance of the participants while discovering a 3D scene. From the perspective of urban participatory e-planning, we focused on the understanding of the VGE that users have, according to the different tested parameters. Before engaging a participant to complete participatory tasks (such as giving an opinion or proposing alternative planning solutions), which employ a VGE, it is crucial for the authorities to ensure that users understand accurately the project depicted within the 3D scene. Without this comprehension, the relevance of these participants' inputs can be questioned. Therefore, the assessment of the user's performance investigates these first understandings.

8.5.2.1. VGE representations

Heterogeneous representations applied to the VGE were produced to investigate their impact on the performance of participants. A representation is defined as a combination of style elements (the textures of 3D objects) and Level of Detail (LOD). We selected two abstract LOD to shape the buildings: LOD 1 and LOD 2. LOD 1 is created by extruding the facades of a building from its footprint, and LOD 2 adds the shape of the roof to the LOD 1 model (Biljecki et al., 2016). These buildings were textured with three different methods: (1) *color*, where the dominant color of the facade and the roof was applied to the surface of the 3D model; (2) *texture*, where a photo-realistic texture covered the raw building; and (3) *focus*, where one of the buildings was modeled with remarkable colors (i.e., white for the facades and red for the roof). From these two aspects, we designed four representations: *LOD 2 + color* (Col2), *LOD 1 + color* (Col1), *LOD 2 + textures* (Tex2), and *LOD 2 + focus* (Foc2) (Fig. 8.2). The representation *LOD 2 + color* was the control; and the other representations were created by adjusting one aspect of the control. From the three resulting representations, we aspired to evaluate the impact of three features on user perception: (1) a decrease in the scenes' details via the reduction of the buildings' LOD; (2) the addition of visual complexity with the photo-realistic texture; and (3) the integration of visual cues via the remarkable building colors, with these cues aimed at highlighting the concerned urban project within its surroundings. To limit the duration of the study, we restricted the use of these four representations only to specific tasks. Fig. 8.1 shows the order of their display.

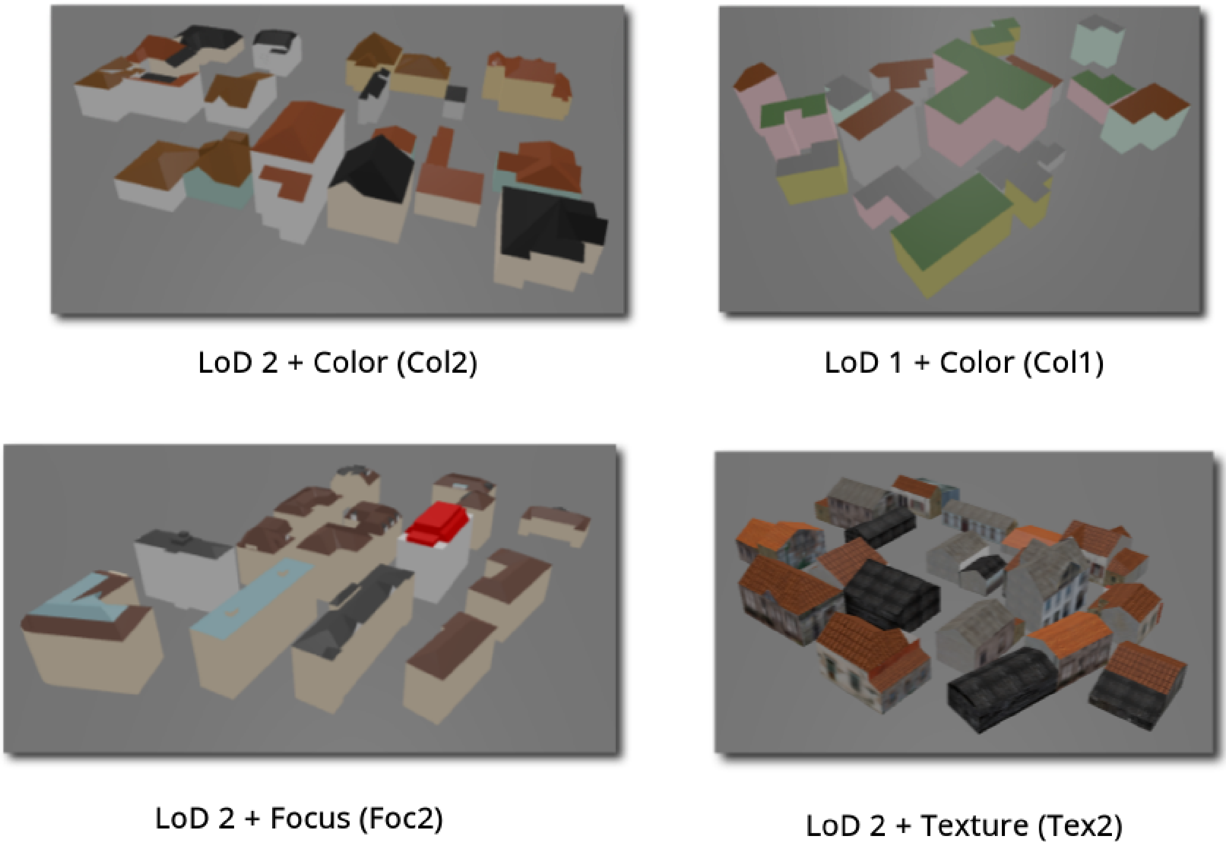

Figure 8.2. *VGE representations used in this experiment*

8.5.2.2. Metaphors

Three metaphors were implemented in order to simulate the practice of VGE in urban participatory planning to assess their impact on users' performance. The first metaphor (batches 1 to 4, Fig. 8.1) aims at simulating the use of an interactive VGE that can be manipulated by the participants at any time during a participatory session. The second metaphor (named *memory*, batch 5, Fig. 8.1) intends to reproduce the broadcast of a video only seen once by the participants at the beginning of a session; this setup was translated by having the VGE and the pre-selected answers not visible simultaneously. The third metaphor (named *static*, batch 6, Fig. 8.1) mimics the use of static images, such as photo-montages, or architectural designs to foster the discussion between participants in a participatory context. Therefore, no interaction was possible with the VGE. The two last metaphors were introduced to evaluate the differences between interactive VGE and typical urban participatory processes.

The interaction with the VGE was possible around a two degrees of freedom rotation (roll with ↑↓ and yaw with ←→). These basic controls aspired to enhance the engagement of the participants with the VGE by making users active in the interaction, without adding extensive complexity for the lay users. The manipulation of the VGE followed some rules to accommodate the objectives of the study: (1) the entire 3D scene was always visible during rotations; (2) zoom and pan control were not permitted; and (3) participants could pivot around the scene (yaw rotation) at their discretion, but the roll was restricted between 0 (horizontal view) and π/4 (bird's-eye view). This last rule aimed to restrain the participants to see the model from below, or through a vertical view. A vertical view could be relevant in a participatory context, for instance, by helping the orientation of the participants within the VGE. However, due to its similarities with the 2D map, this point of view was antagonistic to some tasks designed in the study.

8.5.2.3. Tasks

We designed the tasks considering two factors: (1) to be suitable for the analysis; and (2) to be realistic enough for a participatory approach perspective. Each task had a comparable layout: on the top was a question describing the task to complete; on the left was the VGE with which users could interact to resolve the task; and on the right were four pre-selected answers in the form of text, images, and clickable elements. The tasks' distribution within the batches is presented in Fig. 8.1. We designed four different tasks that were offered to the participants:

- *Guess layout* – participants were asked to identify the 2D footprint that matched the depicted VGE. This task was conducted to assess how participants were able to switch from a VGE to a 2D map. This activity is relevant for a participatory context because 2D documents are often used in sessions with participants.

- *Guess lowest/highest* – participants had to determine the lowest/highest building of the VGE by selecting the correct building on the 2D map that they had previously chosen. This task aimed to evaluate how participants perceive the buildings' heights in an interactive VGE setup. With the progressive densification of the cities, the height of the buildings is a major concern of the local population and is frequently raised in urban participatory sessions (Ruming, 2018; Ruming et al., 2012). VGE are efficient for communicating about volumes, i.e., via a 3D scene, and the heights of the buildings are more straightforwardly perceived than with other supports such as 2D maps (Schroth et al., 2011; Sheppard & Cizek, 2009).

- *Guess viewpoint* – participants had to assess if two green spheres (embedded in the VGE) were visible or not from a viewpoint symbolized by a red sphere. This task is also relevant in a participatory context. Indeed, integrating a future project raises concerns by citizens about the visibility of the new project in the local landscape. A question often raised in a participatory session that uses a VGE is "Can I see the project from my window?".

8.5.3. Participants' Demographics

From the 17th of July to the 27th of October 2020, 107 participants (35% female) took part in the study. The age of the participants ranged from 17 to 67 years old (med = 33), with most of them holding a graduate-level degree or higher (83.2%). Their consumption of 3D was equally distributed. We estimated their spatial abilities and perceptions via a psychological test, namely the Water-Level-Problem (Piaget & Inhelder, 1956), which is an elementary exercise widely used for this purpose in the scientific literature (Linn & Petersen, 1985; Voyer et al., 1995). Its goal is to ask a participant to draw the water level of a glass that has been tilted; any incorrect answers suggest poor spatial abilities. Table 8.1 summarizes the socio-demographic characteristics of the participants. In the feedback survey, the participants evaluated the overall study positively, with an average mark of 4.01 out of 5 (2 individuals had no opinion). Concerning the difficulty, the opinion was divided between an average and relatively hard study, with a mark of 4.25 out of 7 (2 individuals had no opinion).

socio-demographic characteristics	Mean (sd)	N (%)
Gender		
Male		69 (64.5)
Female		38 (35.5)
Age	37.7 (12.3) min = 17; max = 67	
Education		
Master or higher		64 (59.8)
Bachelor		25 (23.4)
Undergraduate *		4 (3.7)
Other		13 (12.2)
No Answer *		1 (0.9)
3D Consumption		
Daily		27 (25.2)
Weekly		31 (29)
Monthly		29 (27.1)
Yearly or less		20 (18.7)
Water-Level-Problem		
Pass		89 (83.2)
Fail		18 (16.8)

** categories not weighed in the statistical analysis.*

Table 8.1. Socio-demographic characteristics of the study's participants

8.5.4. Data Collection and Analysis Methods

During the experiment, data on user performance was collected alongside socio-demographic characteristics of the participants. We evaluated the performance via three variables: (1) the correctness of the answers (count of accurate answers), (2) the inputs count (number of times a user pressed a control, i.e., the count of camera positions), (3) and the time spent to achieve a specific task (from a new task display to the validation of the answer). Also, further information on user interaction was gathered to better describe how the scene was manipulated: camera positions, duration of the inputs, and rotation orientation (Chassin, Cherqui, et al., 2021). From these variables, we assumed that hardship in manipulating the VGE will be translated by a drop in correctness and an increase in both the inputs count and the time spent on a specific task.

The statistical analysis was executed with Python. Based on the results, non-parametric tests were used. Table 8.2 describes the analysis that was undertaken. For categorical data, three steps were conducted: (1) overall differences analysis with a Kruskal-Wallis test (KW_H); (2) if significant, one by one comparison with a Wilcoxon rank-sum test (W_U); and (3) false discovery rate correction via a Benjamin-Hochberg procedure (p_{BH}). For continuous ordered data, a Kendall rank correlation coefficient (K_τ) was calculated to assess their relation. The outputs of all the statistical tests that were conducted in this study are depicted in Appendix D.

Data type	Tests used	Parameter evaluated
Categorical data (cat>2)	(1) Kruskal-Wallis for overall significance (2) Wilcoxon rank-sum test for paired significance (3) P-values false discovery rate correction via Benjamin–Hochberg procedure	Batches
Paired data (2 categories comparison)	(1) Wilcoxon rank-sum test	Gender, Spatial Cognition Test
Continuous ordered data	(1) Kendall rank correlation coefficient	Education, Age, 3D consumption

Table 8.2. *Statistical tests applied to the data according to its type. The parameters of this study linked to the data type are shown in the right column.*

8.6. Results

8.6.1. Conceptual Gap: Batches Comparison

The overall results related to the comparison of the different batches (representations, metaphors) are shown in Fig. 8.3, in terms of input count, task completion time, and correctness score. For each batch, only the two first tasks, i.e., *Guess layout* and *Guess highest*, were considered. The tasks *Guess viewpoint* and *Guess lowest*, being specific to only four or two batches, respectively, have not been assessed for the overall results. The sixth batch does not appear on the input count graph, because participants could not interact with the static images.

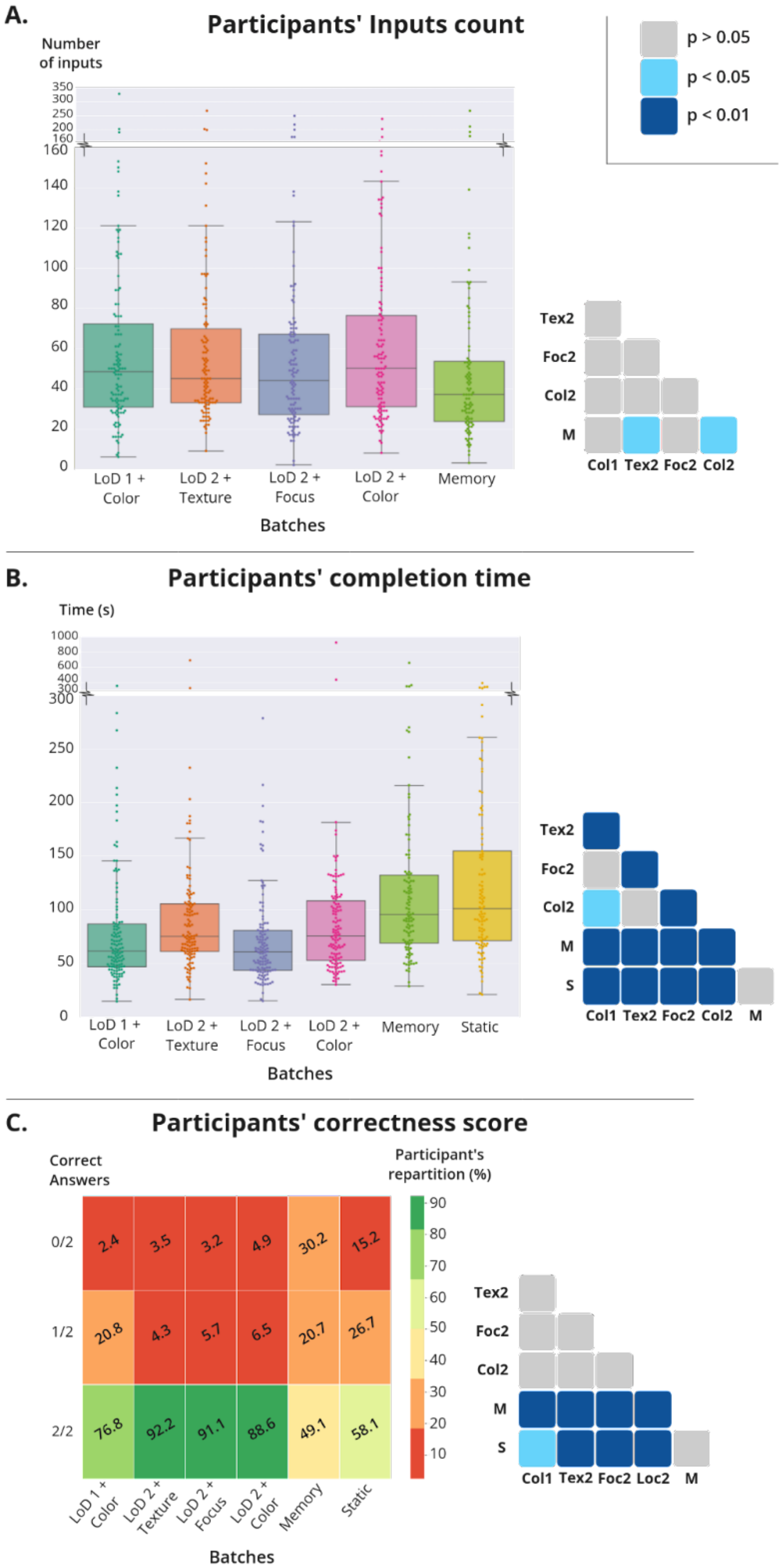

Figure 8.3. *Comparison of the performances of the participants interacting with different VGE representations (or batches) according to three aspects: count of the inputs (A), the time of completion (B) and answer correctness (C). This figure shows the aggregated values of users' performance for the tasks Guess Layout and Guess Highest. The p-value of each computed pair of VGE representations is shown on the right side of each figure*

8.6.1.1. Impact of the VGE representations on user performance

To appreciate which aspects of the VGE representations impact the participants' performance, we analyzed the inputs, time, and correctness. These three parameters were recorded during each of the tasks for the four different representations (described in Section 8.6.2). The results are shown in Fig. 8.3.

For the count of inputs, we did not identify any significant difference between the representations (KW_H = 2.776, p = 0.427). Thus, we did not carry out additional tests.

For the completion time, we noticed a meaningful discrepancy between the representations (KW_H = 23.064, $p < 0.001$), therefore we can reject the null hypothesis, i.e., the participants performed differently in at least one representation. To identify which representation took more time to complete, we applied a Wilcoxon Rank Sums test. We did not establish divergence between the pairs **Col1** vs. **Foc2** (W_U = 0.935, p_{BH} = 0.404), and **Tex2** vs. **Col2** (W_U = 0.544, p_{BH} = 0.587) which implies that the participants required analogous time to complete their tasks on these representations. For the remaining pairs, we observed significant differences: **Col1** vs. **Tex2** (W_U = -3.181, $p_{BH} < 0.01$), **Col1** vs. **Col2** (W_U = -2.440, $p_{BH} < 0.05$), **Tex2** vs. **Foc2** (W_U = 4.095, $p_{BH} < 0.001$), and **Foc2** vs. **Col2** (W_U = -3.490, $p_{BH} < 0.001$). From these results, we can claim that participants were quicker, on average, to complete their tasks with the representations **Col1** and **Foc2**. The two other representations, namely **Tex2** and **Col2**, led to a longer completion time.

For the participants' correctness, we demonstrated with a Kruskal-Wallis test that at least one batch is distinct from the others, and the null hypothesis is indeed rejected (KW_H = 14.789, $p < 0.01$). However, after a one-to-one comparison, the Benjamin-Hochberg procedure (or false discovery rate) did not produce any significant differences.

8.6.1.2. Impact of the metaphors on user performance

To investigate which parameters of the participants' performance are affected by the participatory setup (portrayal gap), we added batches 5 and 6, namely *memory* and *static* to the analysis. The results are depicted in Fig. 8.3, with batches *memory* and *static* that follow the first four batches.

For the count of inputs, we established a significant difference over the batches (KW_H = 12.058, $p < 0.017$). According to the Wilcoxon Rank Sums paired test, we observed that the metaphor *memory* does not differ from the batches (i.e., representations) **Col1** (W_U = 2.418, p_{BH} = 0.052) and **Foc2** (W_U = 1.546, p_{BH} = 0.244). However, a significant divergence was revealed with **Tex2** (W_U = 2.798, $p_{BH} < 0.05$) and **Col2** (W_U = 3.092, $p_{BH} < 0.05$). Therefore, this result indicates that the participants were manipulating the VGE less for executing their *memory* task than they did in the batches **Col2** and **Tex2**.

For the participants' completion time, we noticed that the addition of the two metaphors demonstrates a greater value for the Kruskal-Wallis test (KW_H = 86.274, $p < 0.001$). The Wilcoxon Rank sums test indicates a strong contrast between the two metaphors (*memory* and *static*) and the rest of the batches. Therefore, we can presume that the participants spent more time on the tasks associated with the batches, *memory* and *static,* than on the first four batches. Furthermore, we did not notice a significant distinction within the pair *memory* vs. *static* (W_U = -0.873, p_{BH} = 0.410).

For the participants' correctness, we established that introducing the two metaphors led to a higher value for the Kruskal-Wallis test (KW_H = 110.544, $p < 0.001$). We observed sharp contrasts for all the pairs containing *memory* or *static* ($p_{BH} < 0.001$), with less pronounced differences only for the pair **Col1** vs. *static* (W_U = 2.772, $p_{BH} < 0.05$). Consequently, participants seem to have a better performance with the default interactive VGE, which was used in the first four batches, rather than with other metaphors. The pair *memory* vs. *static* did not show a significant difference.

8.6.2. Comparison of Population Socio-demographic Characteristics

The second section of the results aims to present the variations introduced by the idiosyncrasies of the users in terms of performance (inputs, time, correctness). These results are depicted in Fig. 8.4 and Table 8.3. The significance of five socio-demographic parameters (gender, age, education, 3D consumption, and Water-Level-Problem) has been evaluated. All the batches were aggregated, resulting in one value per criterion per individual.

8.6.2.1. Gender

The performance of the two gender groups is comparable for the criteria: input count and completion time. We applied a Wilcoxon rank sums test on each of these aspects; the analysis did not show a correlation for either aspect: input count (W_U = 0.901, p = 0.367), and time completion (W_U = 1.435, p = 0.151). Therefore, males and females analogously manipulated the VGE (independently of the batches or tasks) before submitting their results. However, the participants' correctness score manifests a notable difference between the two gender groups (W_U = 2.916, p = 0.004), where males appear to have a higher score than females.

8.6.2.2. Age

We considered the age parameter as a ranked continuous value. Therefore, we did not create age categories. Thus, we calculated a Kendall rank correlation coefficient to identify any correlation between the age of the participants and their performance. We noticed a positive correlation for the input count (K_τ = 0.143, $p < 0.05$) and the completion time (K_τ = 0.194, p = 0.005). This correlation demonstrates, therefore, an influence of age on the manipulation of the VGE: the elderly appear to manipulate the VGE, in terms of input and time, more than the youth. We did not observe this correlation for the participant's score accuracy (K_τ = -0.108, p = 0.122). Furthermore, we also observed a compelling negative correlation between correctness score and age for the female gender group, illustrated in Fig. 8.4(**C**), (K_τ = -0.384, p = 0.001).

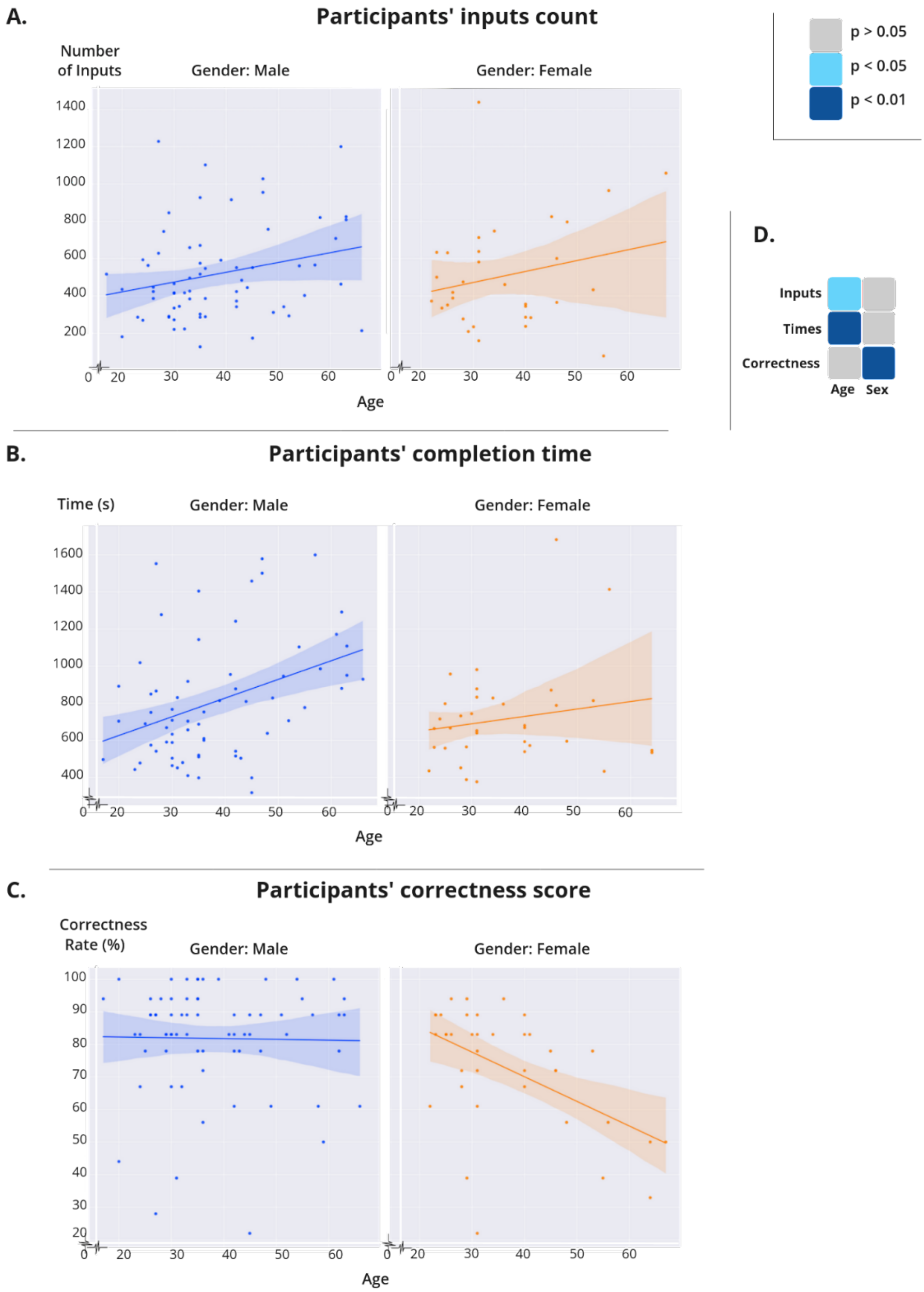

Figure 8.4. *Evaluation of the variation of performances according to users' idiosyncrasies. The variations are depicted according to the age of the participants (abscise) and separated by gender group: male in blue, on the left, and female in orange, on the right. For each diagram, a regression line with its confidence interval is plotted. We assessed three aspects: count of the inputs (A), the time of completion (B), and answer correctness (C). This figure shows the aggregated values for the six batches (and five for the inputs count). The p-value of each computed parameter is shown on the right of figure (D)*

8.6.2.3. Other parameters

We also described the relation between other socio-demographic characteristics (namely education, 3D consumption, and water-level-problem) and the participants' performance (see Table 8.3). We did not notice differences in users' performance according to the education level of the participants (analyzed through a Kendall rank correlation coefficient). The 3D consumption presents a significant positive correlation for the completion time ($K_\tau = -0.240$, $p < 0.01$). Therefore, the more acquainted participants are with 3D, the faster they complete their tasks. Lastly, we observed apparent differences between the participants according to the result of the Water-Level-Problem (pass vs. fail). Individuals lacking spatial abilities (fail group) performed significantly below the other group in completing their tasks for all the parameters, with higher input count ($p < 0.01$), longer completion time ($p < 0.05$) and lower correctness score ($p < 0.01$).

Socio-demographic characteristics	Inputs	Times	Correctness
Education	–	–	–
3D Consumption	–	***	–
Water-Level-Problem	***	*	***

– : p-value > 0.05 ; *: p-value < 0.05 ; ***: p-value < 0.01

Table 8.3. *Supplementary findings about socio-demographic characteristics, namely education, 3D consumption, and Water-Level-Problem test.*

8.6.3. User Preferences in Interacting With VGE Representation

During the feedback section of the online survey, the participants were asked to weigh their perceived complexity on the *Guess highest* task according to the four VGE representations. Two questions were asked: the users had to select the most complex representation first, and then the easiest one. This information is pertinent to the study, adding a subjective opinion on the hardship generated by VGE representations. The perceived hardship can be compared to the factual performances of users assessed in the previous sections. The results are depicted in Fig. 8.5 for 98 votes. A few participants voted for the same scene (being at the same time the easiest and the hardest), therefore, they were removed from the results. Most of the participants voted for the portrayal of **Foc2** (37.8%) as the easiest portrayal to perceive the building height. Regarding the hardest representation, the participants voted for **Tex2** (35.7%). The representation **Col1** is in the second position for both the easiest (27.5%) and hardest (23.5%). Surprisingly, we observed in these votes that eight participants answered incorrectly to the tasks related to the representation that they perceived as the easiest.

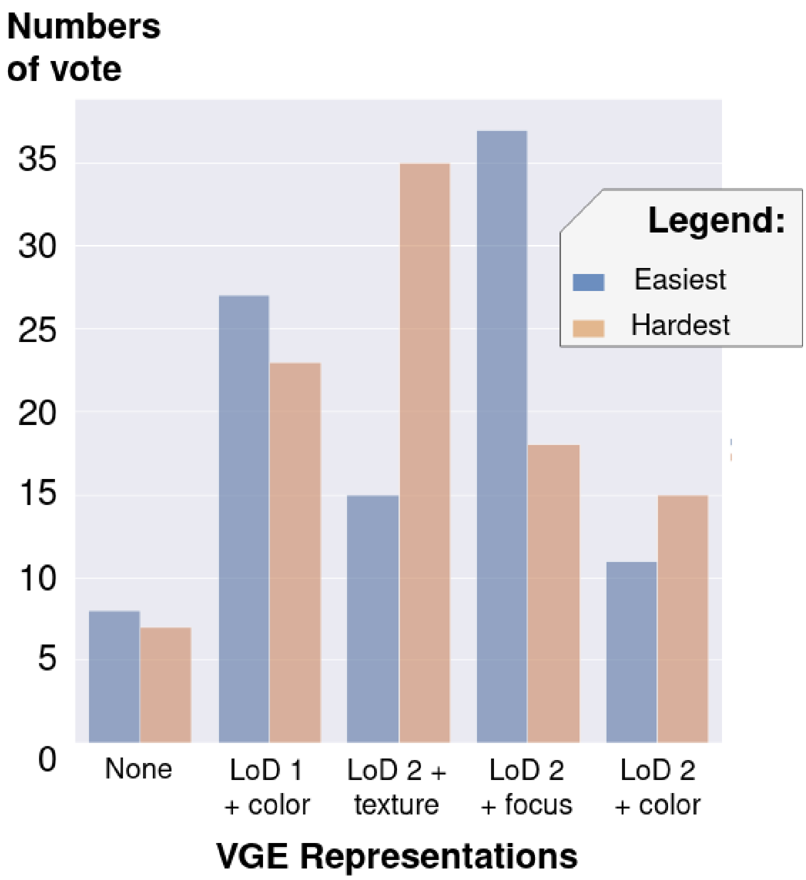

***Figure 8.5**. Results of the participants' vote on the hardest and easiest VGE representation while performing the task Guess highest.*

8.7. Discussions

8.7.1. VGE Representations Affect the Users' Performance Time

We have compared different VGE representations (i.e., LoD and style) in order to assess their effect on users' performance. The data does not demonstrate a connection of this parameter to the input count and the correctness score. However, the analysis shows a decrease in completion time for the representations having a lower LoD or a remarkable element.

The representation **Foc2** has been selected by the participants as the easiest scene to determine the highest building. The distinct building within the VGE, highlighted by color saliency, was the solution of the task *Guess highest*. Salient features highlight specific elements in a bushy landscape (2D or 3D) (Wolfe & Horowitz, 2004). Therefore, these features could focus the users' gaze and their attention. The users could, thus, be guided through cluttered VGE, significantly reducing the time needed to complete a task, as pinpointed in this user study. In an urban participatory approach, this method could focus the participants on a specific issue or component that should be addressed in a participatory session, as hypothesized in the literature (Chassin et al., 2019). However, despite catching users' attention, no conclusions can be drawn on keeping their attention engaged in a lengthy session.

The representation **Tex2** has been considered by the participants as the most difficult representation to determine the highest building of the VGE. Realistic representations incorporate plenty of information, which increases the cognitive load conveyed by the 3D scene (Skulmowski & Rey, 2020). The cluttered information present on the texture (doors, windows, floors, paints, roof tiles, etc.) drives the users to intensify their attention, which could lead to poorer performance compared to more abstract representations (Liao et al., 2017; Smallman & John, 2005). The results of our study are in line with the literature regarding the completion time aspect for the representations **Col1** and **Foc2**. However, we did not observe significant differences between **Tex2** and **Col2**, indicating a relatively small impact of visual cluttering on users' performance, which has already been noted in the literature (Lokka & Çöltekin, 2019). Therefore, the use of abstract or realistic representation in an urban participatory context should not be evaluated by its impact on users' performance, but according to the urban project dimensions, such as temporality, tasks, and uncertainties (Chassin et al., 2019; Hayek, 2011; Judge & Harrie, 2020).

The representation **Col1** was perceived both as helping and hindering in distinguishing the building heights. On the one hand, the positive feedback from the participants is illustrated by an improvement in users' performance (in terms of completion time) without loss of correctness. During a participatory session, participants could, therefore, efficiently focus on a specific task, avoiding spending time and energy on perceiving and understanding the specificities of the elements that are displayed within a VGE. On the other hand, this antagonism reported by the participants is also supported by the fact that eight users, who voted **Col1** to be the easiest, did not select the correct answer on the related task. This representation indeed appears to be confusing of its apparent simplicity. The lack of differentiation between the buildings, introduced by the basic cubic shape, appears to decrease the legibility of the overall VGE (this poor contrast was unfortunately accentuated by similar colors).

8.7.2. Several Socio-demographic Characteristics Affect Users' Performance

We have assessed the impact of five socio-demographic characteristics, namely age, gender, education, 3D consumption, and Water-Level-Problem on users' performance based on 3D tasks. The results show a clear correlation between the correctness score of the participants and their gender or interpretation of the Water-Level-Problem. Further relations have also been established, such as input count vs. age & Water-Level-Problem, and completion time vs. age & 3D consumption & Water-Level-Problem.

Socio-demographic characteristics act as an essential feature of participatory approaches. Each session aspires indeed to reach a specific targeted population that could extensively fluctuate (e.g., gender, age, location, profession) according to the context of the session (i.e., addressed thematic). However, the tools that are adopted by municipal officials can mobilize these targeted groups only to a certain degree (Chassin et al., 2019); this limited extent also affects urban 3D participatory e-planning solutions. A suitable solution to limit this hindrance, and promote more inclusivity in the participatory sessions, would be to diversify the participatory tools, which are adopted to reach the targeted public. However, implementing this approach can be complex depending on various factors: political, economic, cultural, societal, etc. Therefore, acknowledging and understanding the differences between participants is crucial in the design of participatory tools (e.g., VGE), which should be responsive to users' backgrounds, skills, and expectations. Based on the findings described in the previous section which demonstrate a partial impact of the VGE representation on user performance, we would recommend designing a custom representation that results from a dialogue between a user and a digital agent (Christophe, 2011), which can be embedded, if users' social-demographic characteristics are known in advance. A personalized representation will have a limited impact on the user's performance but could enhance their motivation to be engaged with the VGE.

One vivid debate on the adoption of VGE in urban participatory planning is the mobilization of the elderly and the young (Bouzguenda et al., 2021). The results suggest that age is related to a loss of efficiency (input count and completion time), or at least to more exploration of the VGE. However, no loss of correctness score has been established for the age parameter, in the online context of the study that attracted participants who were certainly more tech-savvy than the broader population. Training individuals beforehand could balance this reduced efficiency, as suggested by the results for 3D consumption. Therefore, in a participatory session context, an optional tutorial could be implemented to introduce and facilitate the use of VGE tools for individuals who desire to do so.

Nonetheless, one population segment presents a nonconformity. We observed a strong decrease in the correctness score according to age for the female demographic group. The number of individuals being relatively low, this assumption deserves particular attention and further investigation. This drop implies the need for participatory approaches to adapt the practice. The 18% of participants who failed on the Water-Level-Problem (thus lacking spatial abilities) reinforced this need to design flexible approaches. Diversification of the participatory tools (not only spatial-based) could support a better inclusion of these demographic groups. Nevertheless, two challenges arise: (1) how to reduce the spatial heaviness of mediums used in participatory sessions on issues that are profoundly inscribed in the territory; and (2) how to consider the local expertise of citizens having a different spatial perception.

8.7.3. Towards an Enhancement of VGE Practices in Urban Participatory Planning

We investigated the practicability of typical participatory setups, namely video broadcasting and architectural static visuals, by implementing two metaphors (memory and static). Our analysis demonstrates a clear lack of performance of these methods compared to the use of an interactive VGE for tasks related to the evaluation of buildings' heights and the transition between 2D vs. 3D views.

3D geo-visualizations are acknowledged to foster the sense of place, i.e., to establish a connection between the real-world and the virtual representation of a place (Newell & Canessa, 2015). This sense of place is crucial in urban participatory planning, notably by allowing participants to relate to the virtual representation in order to discuss tangible urban issues. Furthermore, the interactivity promoted by VGE supports the understanding and representativeness of the scene that is portrayed (Sheppard & Cizek, 2009). The results of this study on the interactive setup, namely active interaction (interactive VGE), passive interaction (memory), and non-interaction (static) can be compared to previous results found in the literature.

First, the use of static images limits the amount of information that an interactive 3D geo-visualization can convey. Indeed, the performance of the participants is reduced with the use of static images, as demonstrated by the significant differences in users' correctness scores. Similar findings can be found in the literature (Herman, Juřík, et al., 2018; Keehner et al., 2008; Kubíček et al., 2019; Schroth et al., 2011). However, surprisingly, we observed that interactivity appears to reduce the time needed for completing a task, which is not in line with other studies (Herman, Juřík, et al., 2018; Juřík et al., 2020). This divergence could be linked to the task to complete, the type of data that is depicted in the VGE, or to the scale of the VGE. In our setup, VGE had a reduced spatial extent with a limited manipulation that could lead users to restrict their exploration.

Second, the use of video that is broadcast once at the beginning of a participatory session forces the participants to memorize and understand complex aspects regarding the implementation of a future urban project. The subsequent contributions of participants are relevant only if they can accurately and instantly recall the information that they had watched. However, our results (in a memory setup that uses interactive VGE) demonstrate a drop in users' correctness scores. This result is in line with the literature that established the existence of immediate inaccuracies in route navigation recall after seeing a video with an egocentric perspective; these inaccuracies tend to increase after a delay (Lokka et al., 2018). There is evidence to suggest that active interaction facilitates the encoding of (spatial) information compared to a passive setup (Chrastil & Warren, 2012). This encoding is essential for learning and also for developing comprehensive knowledge about a (spatial) situation. Passive setup can be improved by recording beforehand a set of optimized viewpoints that would be passively displayed during the exploration of the 3D models (Keehner et al., 2008).

The metaphors, memory and static, appear to be less suitable in a participatory context than in an interactive VGE. The participants perform better with interactive VGE, which allows them to select their own point of view and not be restrained by vantage views carefully selected beforehand by the authorities. By restricting the free exploration of the VGE, the local authorities are empowered to share a carefully selected collection of perspectives, which aims only to show favorable aspects of the project in order to influence citizens' judgments.

8.7.4. Limits of the Survey

This study was conducted online, and we had no control over the participants completing the experiment. The population that takes part in online surveys is often skewed toward male, tech-savvy, educated people (Bethlehem, 2010). Thus, we observed a preponderance of these socio-demographic characteristics within our study, which are not representative of the broad population. This imbalance is notable for the elderly, who were mainly tech-savvy and therefore relatively comfortable in manipulating VGE. Our results should be considered accordingly.

Furthermore, buildings were the only city elements depicted within the VGE. Other common elements, such as trees, gardens, street furniture, light poles, and vehicles were not modeled. This restriction limited the time needed for the development of the study and reduced the size of the VGE. Indeed, the technical setup of the participants was not controlled. The performance of the users' computers could have produced delays in the display of the VGE. This situation was raised once in the comment section for batch **Tex2**. Moreover, another participant declared having to restart the study several times because their computer was turning off during the survey.

The results of this research are based on an experimental study where the participants manipulated VGE for approximately 20 min. However, a typical in-person participatory session is spread over several hours. Therefore, our experimental setup cannot simulate this expanded time of engagement that could drive the participants to exhaustion, reducing their performances in manipulating VGE or tainting their judgment.

8.8. Conclusion

In this study, we developed a user experiment to investigate the performance of the users (n = 107) when interacting with a VGE. Tasks related to urban participatory sessions were implemented, and the results were evaluated through three gaps: (1) a conceptual gap portrayed by the design of multiple levels of abstraction for the VGE; (2) a cognition gap observed via the number of participants and their variation in terms of the socio-demographic characteristics; and (3) a portrayal gap considered over the simulation of three participatory setups using VGE.

The results demonstrated that a higher level of abstraction or salient elements significantly decreased the time needed to complete the tasks of the experiments. Time is also an important aspect influenced by socio-demographic characteristics and past experiences, namely age and consumption of 3D tools. Furthermore, we observed that participants who failed the Water-Level-Problem experienced hardship when interacting with VGE. This last result is crucial for the adoption of VGE in urban participatory practices because these users account for nearly 20% of the total participants. The local authorities should, therefore, consider other mediums (or tools) to collect the contribution of these urban dwellers in order to, first, limit bias in the decision, and second, increase the inclusivity of the approach.

Moreover, this study showed that the current practices of 3D geo-visualizations in urban participatory sessions are poorly adapted to the potential of VGE. Using videos or static images seems to limit the performance of the participants on tasks that are related to participatory planning. Therefore, this study highlights the need to enhance current practices with interactivity in order to improve the quality of the participatory approaches via better contributions and a better understanding of urban projects. Ten years ago, E. Lange stated “We can visualise. Now what?” to emphasize that the technical obstacles in 3D were mainly lifted (Lange, 2011). Since then, many studies have contributed to the assessment of users’ perception and behavior while facing VGE. This knowledge base provides several guidelines to design better VGE, more centered on users. It is now time to lift the skepticism of the local authorities in order to finally democratize the practice of interactive VGE in urban participatory planning. Therefore, we aim to develop a prototype of an online platform for urban 3D participatory e-planning, which would be augmented by the findings of this study and the current state of scientific knowledge in participatory planning. After its implementation, we aspire to consult the authorities in the adoption of this new generation of participatory tools.

The last contribution of this user study is the surprising success of the online format. The experiment was planned in-person, like most studies about user cognition. However, with the unpredictable context of the COVID-19 pandemic, we were forced to think outside the box and adopt a different method, similar to others (Griffin et al., 2021). From a user study that was planned to take place for a couple of hours, we had to transform our procedure to suit the online format. Some aspects had to be deleted and others to be added, such as the gamification elements. This process was challenging, and the fact that participants could complete the study freely at any time, on their personal devices, surely added new and uncontrolled parameters that might be difficult to assess. Nonetheless, this flexibility allowed us to reach more than a hundred people during the summer months following the first wave of the pandemic. The resulting conclusions of this study are also based on solid data, which were only made possible by the online format. With this study and the availability of the in-house original files in open source, we contribute to the development of potential methods to address challenges in conducting online user studies.

URLs

Google Earth: google.com/earth/; Facebook: facebook.com; Linkedin: linkedin.com; Reddit: Reddit.com (r/SampeSize); GeoRezo: georezo.net; OpenStreetMap: openstreetmap.org; Blender: Blender.org (version 2.82); Three.js: Threejs.org (version 0.114.0); Python: Python.org (version 3.7.5).

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Chapter

9. Paper E: How Do Users Interact With Virtual Geographic Environments? Users' Behavior Evaluation in Urban Participatory Planning

List of abbreviations for the chapter:

CGI: Computer-Generated Imagery
VGE: Virtual Geographic Environments
LOD: Levels of Detail
sd: Standard Deviation

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9.1. Preface

This chapter presents a new perspective on the data collected in the previous chapter. The assessment of participant performances is crucial to understanding how the practices and the 3D mediums affect the urban dwellers engaged in participatory sessions. The quantification of the performance demonstrates settings that are more efficient than others. However, the performance alone cannot describe the full complexity of the inter-dependence between the participants, the practices, and the mediums. Also, improving the 3D mediums to promote better inclusivity of the participatory approaches. Therefore, in this chapter, I investigate further the data collected in the previous chapter. The objective is to understand the behavior of the participants better while manipulating a virtual geographic environment (VGE). The evaluation of behaviors could support the identification of elements of design or interaction that could be improved to offer an enhanced experience while interacting with the VGE. Designing augmented experience could turn the use of 3D mediums in participatory practices more appealing, or at least create engagement strategies that could facilitate the use of VGE for non-expert participants.

Publication and personal contributions

Chassin, T., Ingensand, J., Touya, G., and Christophe, S. (2021) *How do users interact with Virtual Geographic Environments? Users' behavior evaluation in urban participatory planning*, Proc. Int. Cartogr. Assoc., 4, 19, doi: 10.5194/ica-proc-4-19-2021.

Personal contributions: formulation of research goals and aims, development and design of methodology, software development; designing web applications, analyzing and synthesizing study data, figures preparation, manuscript writing.

9.2. Abstract

For the past twenty years, the adoption of Virtual Geographic Environments is thriving. This democratization is due to numerous new opportunities offered by this medium. However, in participatory urban planning, these interactive 3D geo-visualizations are still labeled as very advanced means and are only scarcely used. The involvement of citizens in urban decision-making is indeed carefully planned ahead to limit off-topic feedback. A better comprehension of Virtual *Geographic* Environments, and more specifically of users' strategic behaviors while interacting with this medium could enhance participants' contributions. The users' strategic behavior was assessed in this article through an experimental study. A total of 107 participants completed online tasks about the identification of 3D scenes' footprints, the comparison of buildings' heights, and the visibility of objects through the scenes. The interactions of the participants were recorded (i.e., pressed keys, pointing device interactions), as well as the camera positions adopted to complete specific tasks. The results show that: (1) users get more efficient throughout the study; (2) interruptions in 3D manipulation appear to highlight difficulties in interacting with the virtual environments; (3) users tend to centralize their positions within the scene, notably around their starting position; (4) the type of task strongly affects the behavior of users, limiting or broadening their explorations. The results of this experimental study are a valuable resource that can be used to improve the design of future urban planning projects involving Virtual Geographic Environments, e.g., with the creation of personalized 3D tools.

9.3. Introduction

The worldwide presence of Google Earth and the development of highly realistic video games or Computer-Generated Imagery (CGI) place non-experts as regular consumers of 3D, also considered as Virtual Geographic Environments (VGEs) (Lin & Gong, 2001). Additionally, the development of intuitive techniques to interact *with* these digital 3D objects lowers their entry cost (Jankowski & Hachet, 2015). VGEs are, therefore, gradually perceived as a tool not limited to expert usage. This shift inspires the design of several applications that are based on the participation of a broad, non-expert population. This interest is experienced by a large range of sectors (Biljecki et al., 2015), including urban planning, where the benefits of 3D geo-visualizations have been acknowledged for twenty years (Al-Kodmany, 2002). VGEs are considered as 3D communication mediums that provide a valuable opportunity to fulfill the primary objectives of participatory approaches in urban planning, namely participants gaining knowledge and broadening their perspectives about the urban project (Joerin et al., 2009). However, the authorities currently disregard the adoption of VGEs in a real-world context because of concerns about the usability of these tools by citizens. The position of the authorities is thus not in line with the previous considerations. In this study, we argue that a better understanding of how users interact with VGE could address the authorities' concerns and ultimately democratize the practice of VGEs in urban participatory practices.

Through an experimental study, we aim to investigate the aspects of VGEs affecting users' behavior developed when interacting with a 3D scene. Firstly, some aspects of VGEs in participatory planning other than users' behavior-related studies are presented. Next, we describe the experimental setup designed to evaluate the behavioral aspects. Then, the results are presented regarding four elements encapsulating the mentioned behavioral aspects. Lastly, we extensively discuss the results and their significance for the practice of VGEs in urban participatory planning (and other sectors).

9.4. Related work

Several aspects of VGEs are favorable for participatory practices. They facilitate communication to a broad public and help the appropriation of a hypothetical future urban project by all actors of a participatory approach: experts, politicians, or the population (Jacquinod & Bonaccorsi, 2019). The visualization of these future projects in their surroundings also supports the convergence of users' mental representations in one shared understanding that is common to all users (van der Land et al., 2013). This direct overview of a project proposal tends to limit actors' misconceptions and heterogeneous understanding, which often comes from mental representations based on a conceptual description such as 2D maps or texts. Moreover, the interactivity provided by VGEs encourages users to explore the 3D scene by using their own perspectives and vantage points, which reduces biases introduced by predefined points of view (Downes & Lange, 2015). This exploration also improves the perception and the understanding of the 3D scene's depths, heights, distances, etc. (Dübel & Schumann, 2017; Herman, Juřík, et al., 2018; Sheppard & Cizek, 2009).

However, while interacting with VGEs experts still perform better than laypersons (Herman, Řezník, et al., 2018), who are often accustomed to virtual environments only as passive customers. Indeed, interactivity increases the complexity and the cognitive load conveyed by 3D scenes, which are already cognitively intensive (van der Land et al., 2013). The resulting users' fatigue leads to less effective interaction with the VGE, which may constrain the task(s) to perform. This fatigue varies between users according to specific socio-demographic characteristics, such as age or spatial cognition abilities (Stanney et al., 1998).

The design of VGEs, as a 3D geo-visualization tool, implies several challenges articulated around three categories: the *data* (co-visualization of information from various sources on the same medium); the *users* (communication of a consistent (neutral) message to heterogeneous users, having unique skills, cognition abilities, objectives, and interactive behavior); the *representation* (depiction of information with its set of style and interaction) (Christophe, 2020; Çöltekin et al., 2017). The design of (non-expert) citizen involvement tools should carefully consider these categories, in order to limit the risk of enacting inappropriate VGE practices, which could lead to bias, misinterpretation, inequality in its application (Schroth et al., 2011), and ultimately poor decision-making. A better understanding of how these categories are connected could limit these hindrances and enhance participatory practices.

This research implements an experimental study to investigate one possible connection between two of these categories: representation and users. This connection is evaluated by assessing the development of users' strategic behavior when interacting with VGEs. The users' behavior has already been studied in the literature in an interactive 3D context (Herman & Stachoň, 2016; Ugwitz et al., 2019; Wilkening & Fabrikant, 2013), notably by the reconstruction of a *trajectory visualization* (or user's camera path) from raw users' inputs (Herman, Řezník, et al., 2018). An analogous method will be used in this study.

9.5. Methodology and Experimental Study

9.5.1. Access Dimensions for Interactive Sessions

Designing an urban participatory approach is challenging for authorities. They may experience a tense situation with citizens, which will decide the future of a project. Also, their reputation may be jeopardized, especially if the selected medium proves inappropriate. The authorities are, thus, concerned about the usability of VGEs in a participatory context. These concerns could be addressed by a better knowledge of the interaction between 3D scenes and the users' behavior (understanding, hesitation, performance, inputs, etc.). Therefore, investigating how the 3D representation (in terms of style and detail) affects the users' behavior while interacting with the VGE could contribute to this knowledge. This knowledge can promote the design of VGE that is responsive according to users' idiosyncrasies or the tasks to perform by assisting users with customized assistance, for instance. In this study, the users' behavior will be analyzed via a trajectory visualization over four aspects:

- **(1)** *Learning curve*: VGEs are known to have a rapid learning curve (Zhang & Moore, 2014). Users indeed get accustomed to the 3D medium, i.e., its controls, rules, portrayals, and specificities. Therefore, we expect users to develop a fast understanding of this medium that translates into the development of strategies to get more effective independently from the 3D scene representation.

- **(2)** *Uncertainties*: Manipulating a VGE is challenging for users, even if the controls are kept simple. Times, when users are not interacting with the VGE, are observed in the literature (Herman, Řezník, et al., 2018). We presume this inactivity to be linked to uncertainties or time for mentally rebuilding an understanding of the 3D scene, which could be related to the user's socio-demographic characteristics (age, previous experiences with VGEs).

- **(3)** *Anchor points*: Users create mental images of the scene that anchor their cognition (Couclelis et al., 1987). If the task requires the collection of supplementary information, we suppose users will aim to limit the development of these mental images to ease their cognitive burden.

- **(4)** *Impact of the task*: Distinct tasks require users' specific information to gather in a particular representation. Therefore, we expect that the nature of the task to complete should highly channel users' interactions with the VGE.

9.5.2. Experiment Design

This research presents the second phase of an experimental study aiming at assessing participants' performances with VGEs. The VGEs were built from reduced city models with 16-19 buildings of various representations. The participants were asked to perform tasks articulated around participatory session interests, such as heights, angles of view, and parallels between 2D and 3D representation. In total, 18 questions were set up for the overall experiment with a combination of tasks interactive methods (or metaphors), and representations. The study required an approximate time of 20 minutes for completion. Hereafter, we will adopt the term *batch* to describe all the tasks in a specific representation and metaphor.

VGE representations. Fig. 1 shows all four representations adopted in this study. These representations are based on two Levels of Detail (LoD): LoD 1 and LoD 2 (Biljecki et al., 2016). On these raw LoDs, there were three types of draping enveloping the buildings: (1) *color*, where the dominant color of the building from the satellite images was assessed visually and applied to the model; (2) *texture*, i.e., a photo-realistic texture applied to the building; (3) *focus*, where the color method was applied to each building, but one, the highest, which was colored white with its roof bright red. We introduced the last representation to investigate the impact of visual cues on users' behavior. The four representations were named: *LoD 1 & color*, *LoD 2 & color* (control scene), *LoD 2 & texture*, *LoD 2 & focus* (see Fig. 9.1).

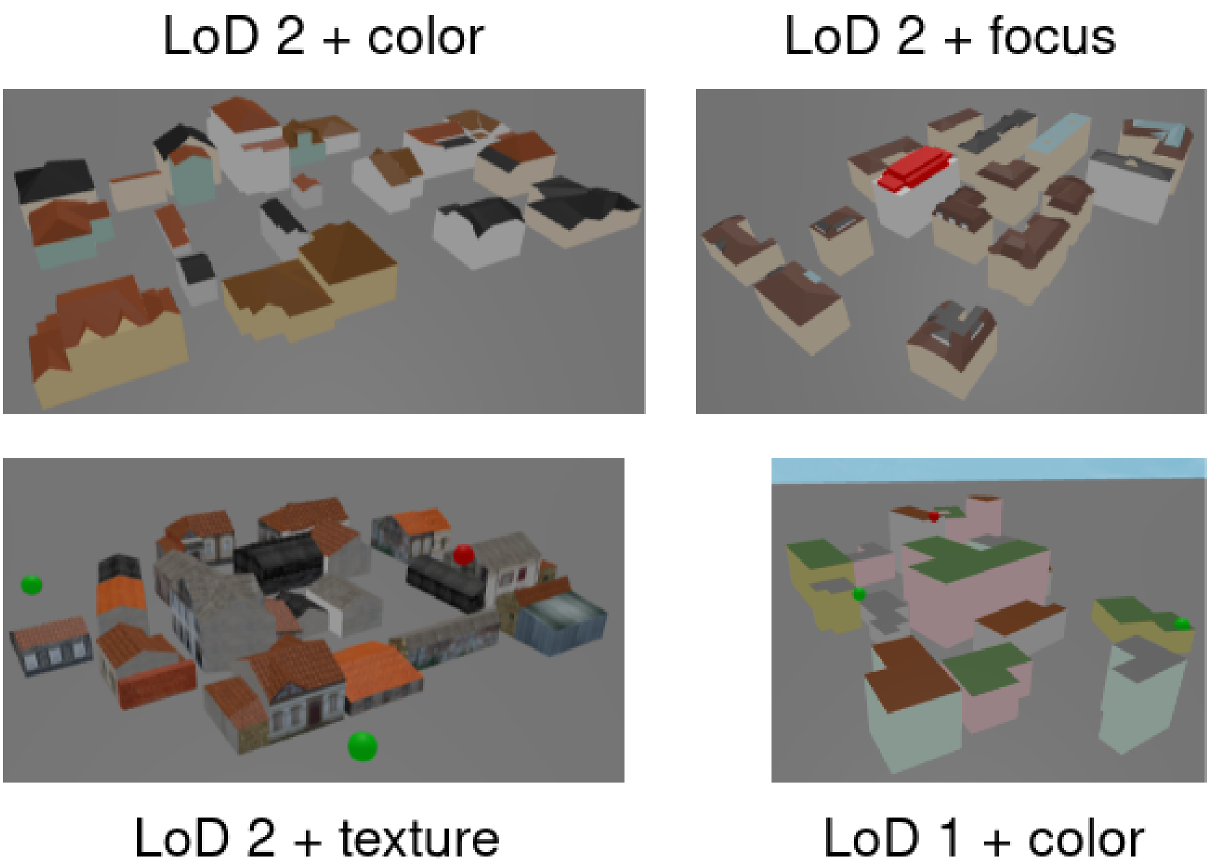

Figure 9.1. *Illustration of the VGE representations used in this study for the first four batches.*

Metaphors. The metaphors implemented for the study aimed at simulating participatory session setups: (1) *"unrestricted"* interactions (batches 1 to 4, Fig. 9.2), where users could freely manipulate the VGEs without constraints of time or number of inputs; (2) *memorization* (batch 5, Fig. 9.2), where the 3D scene was not visible when participants were answering the questions related to a task – this setup aims to simulate the projection of a video, seen only once, before debating topics specific to a participatory session; (3) *static* (batch 6, Fig. 9.2), where the 3D scene was not interactive, simulating the use of photo-montage in a participatory setup. The last metaphor will not be discussed in this study. Participants could manipulate the interactive VGEs via two degrees of freedom (rotation: pitch and yaw) with the arrow keys of the keyboard. The pitch was locked from 0° (horizontal view) to 45° (oblique view) to avoid viewing the 3D scene from under, or from a vertical view (being too similar to the 2D layout of maps). The distance to the VGEs (zoom) was also locked. These interactive rules were introduced to limit the entry cost, and ultimately open the study to anyone with or without technical skills.

Tasks. Participants were asked to complete three kinds of tasks related to urban participatory planning interests. The layout of the pages was similar: a question was asked on the top of the page, on the left was the VGE, with the alternative answers on the right. The three kinds of tasks were: (1) *guess layout*, where the participants were asked to identify which one of 2D map layouts corresponded to the 3D scene; (2) *guess highest* or *guess lowest*, which was about building heights – participants were invited to select the highest or the lowest building on the 2D layout that was previously chosen; (3) *guess viewpoint*, where three spheres were located within the VGE (one was red, the two others were green) – participants were asked to determine which of the green spheres were visible from the red one (both, the closest, the farthest, none).

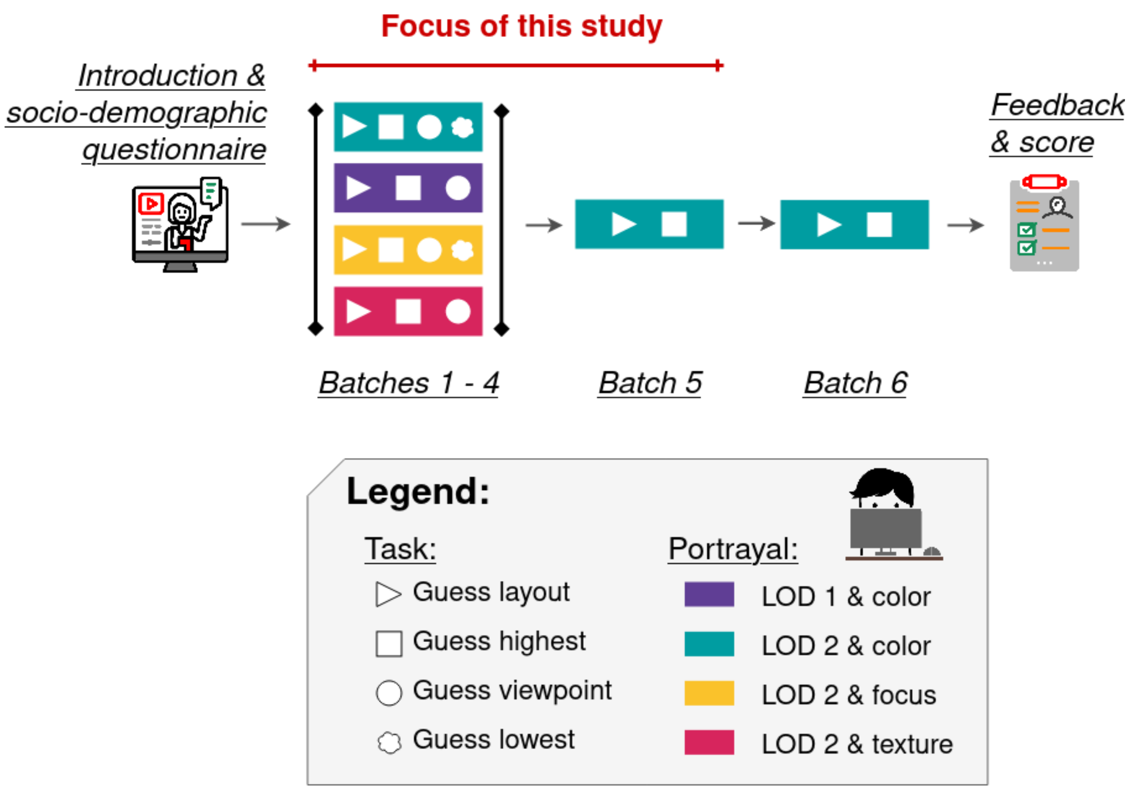

***Figure 9.2**. Detailed outline of the user study*

9.5.3. Collecting User Interactions

While interacting with the VGE to complete their tasks, the inputs of the participants were recorded and transmitted to a database. For instance, a participant pressing the key ← triggers a record of the starting position, the ending position, the duration of the input and the orientation of the rotation (here left). An aggregated result of this raw data is depicted in Fig. 9.3: all camera positions for a specific task and representation are displayed.

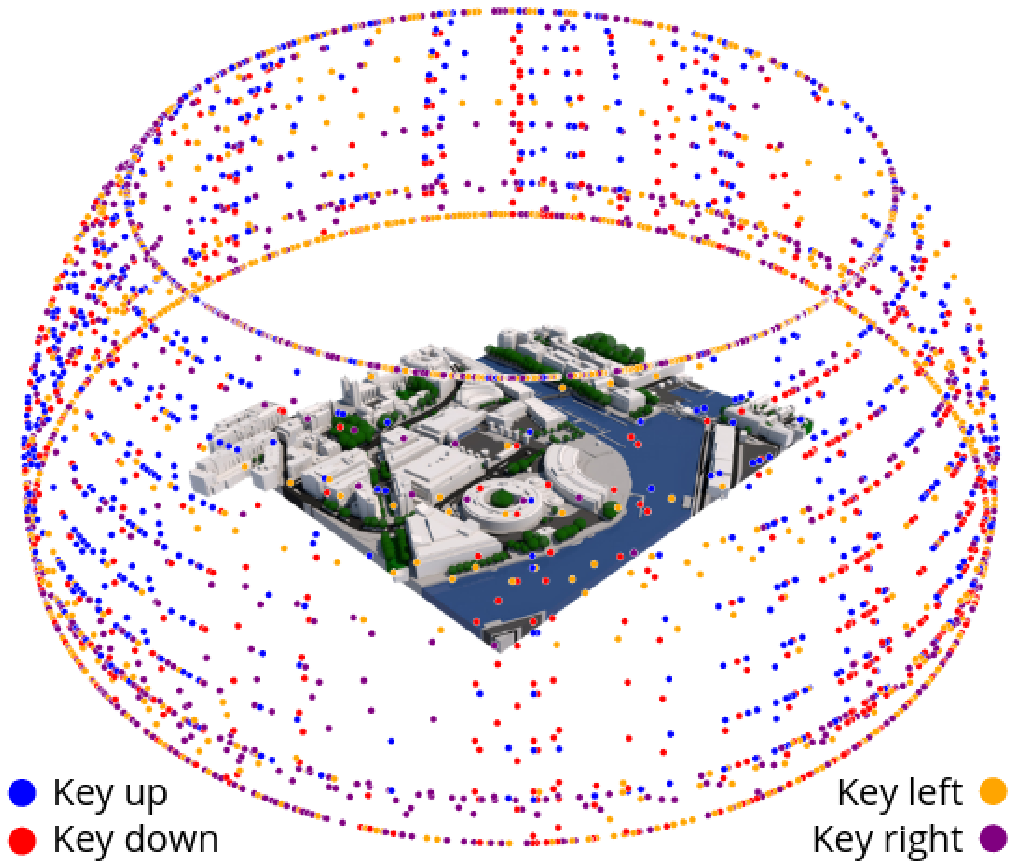

Figure 9.3. *Raw camera positions of users to answer a specific task, in this case, Guess highest on the portrayal LoD 2 + color. The participants control the VGE via vertical and horizontal rotations, forming the spherical segment shape.*

The shape of a spherical segment is constrained by the rules of interaction limiting the participants' position. In addition to the user's camera path, we recorded the user response and time. The VGE is virtually present at the center of this shape (as depicted in Fig. 9.3). Moreover, other information on the setup still needs to be outlined: (1) the starting position of the camera was random (equally distributed between top or bottom of the VGE); (2) the position was always the same for one full batch to avoid user confusion during the task related to the same VGE; (3) none of the 2D layouts were rotated and therefore they were always in the same orientation.

9.6. Participants of the Study

This experimentation was available online between June and September 2020. The study was fully open to the public, with the participants using their own laptops to complete the tasks. Participants were reached over social networks, forums for professionals, and word-of-mouth. The online platform hosting the experiment was from an in-house development, and accessible only from a computer (smartphones were excluded). A total of 107 participants have completed the study. Out of this number, 35.5% were female and 64.5% male. The average age was 37.7 years old (sd = 12.3), fluctuating from 17 to 67 years old. The participants were accustomed to 3D with 81.3% using this medium on a monthly basis.

9.7. Results

9.7.1. VGE Interaction Learning

The learning of new tools (or technologies) by users begins at their first encounter. This assimilation is manifested by an increase in efficiency in using the tool. The estimation of this learning curve is assessed by two parameters in this study: (1) the number of inputs, (2) the time to complete the task. The second parameter was introduced to inquire about the participants' fatigue, with the assumption that this aspect is translated by fewer inputs and shorter answer times. For this analysis, each batch is defined by the combined inputs of *guess layout* and *guess highest*. *Guess viewpoint* and *guess lowest* were excluded from the calculation because these tasks were not asked in every batch.

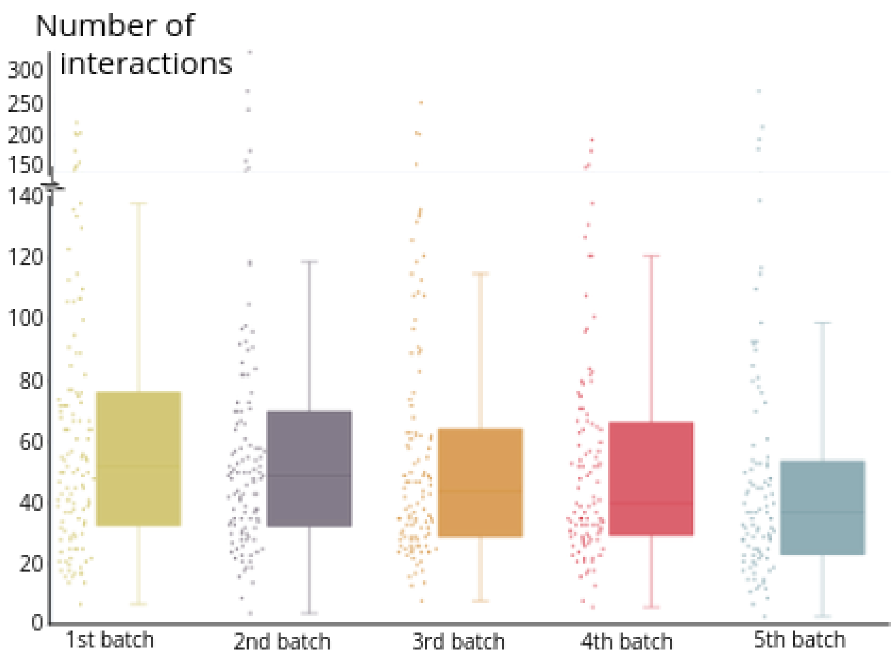

Figure 9.4. *Number of inputs per batch. The batches have been classified by order of appearance for each participant*

Fig. 9.4 shows a decrease in the number of inputs over time. This negative correlation was validated statistically by a Somers' Delta, a non-parametric test for ordinal dependent variables (δ = -.123, p-value < .001). The strength of the relationship between the two parameters is *weak* but notable. For estimating this relation, the number of inputs was aggregated by slices of 10. The same operation was conducted on the time to complete a batch per participant, and no correlation was found.

9.7.2. Participants' Interaction Uncertainties

This concept is estimated by the ratio of VGE interaction time divided by the total time needed to complete the task. Indeed, users experiencing hardship manipulating a VGE will pause for a significant amount of time between their interactions. This interruption may help the users to reassess their situation in the VGE, i.e., evaluate their new position, study the new orientation of the scene, consider their next input, etc. Fig. 9.5 depicts the average ratio of interaction time/total time according to the age and the frequency of 3D use for the task *guess layout* and *guess highest*.

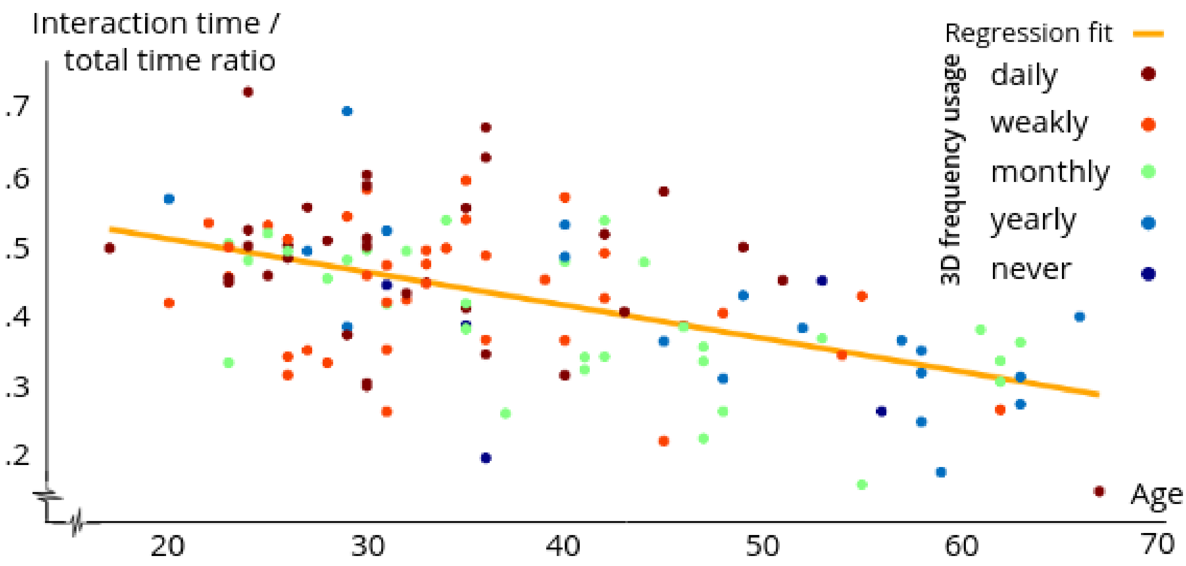

Figure 9.5. Interaction/total time ratio according to age; the color represents the discrete frequency of 3D use.

A few ratios (21) for the *LoD 2 + texture* representation were deleted from the analysis due to a computational error. For the remaining ratios, a compelling relation for the age has been identified with a Somers' Delta test (δ = -.343, p-value < .001). A moderate opposite relation was demonstrated for the frequency of 3D use with δ = .264, p-value < .001.

9.7.3. Anchor Points

To analyze how the users anchor their mental images, two anchor points affecting participants' cognition are considered: (1) the participants' starting orientation, which is defined as the (randomly distributed) yaw angle (i.e., horizontal position, between 0 and 360°) at which a user lands on the VGE; (2) the orientation of the 2D maps' layouts that is established as the (yaw) angle of the VGE at which the 2D maps and the 3D scene orientations are aligned (Fig. 9.6). These two anchor points have been selected because: (1) the first orientation in which a user sees a VGE is crucial – all next orientations that are generated by manipulating the 3D scene are indeed resulting from this first image; (2) users had to exploit specific 2D layouts' orientations that are non-rotatable, thus, users had to adapt their VGE images to match the 2D layouts' orientations. These aspects were analyzed through the camera path which a user adopted to complete a specific task. The two anchor points were characterized by a sphere section encapsulating their orientations (Fig. 9.6). This section was calculated with a 5% margin around the orientation angle, e.g., if the orientation angle was 100°, the bounds of the section were 82°-118° (100-360*0.05; 100+360*0.05).

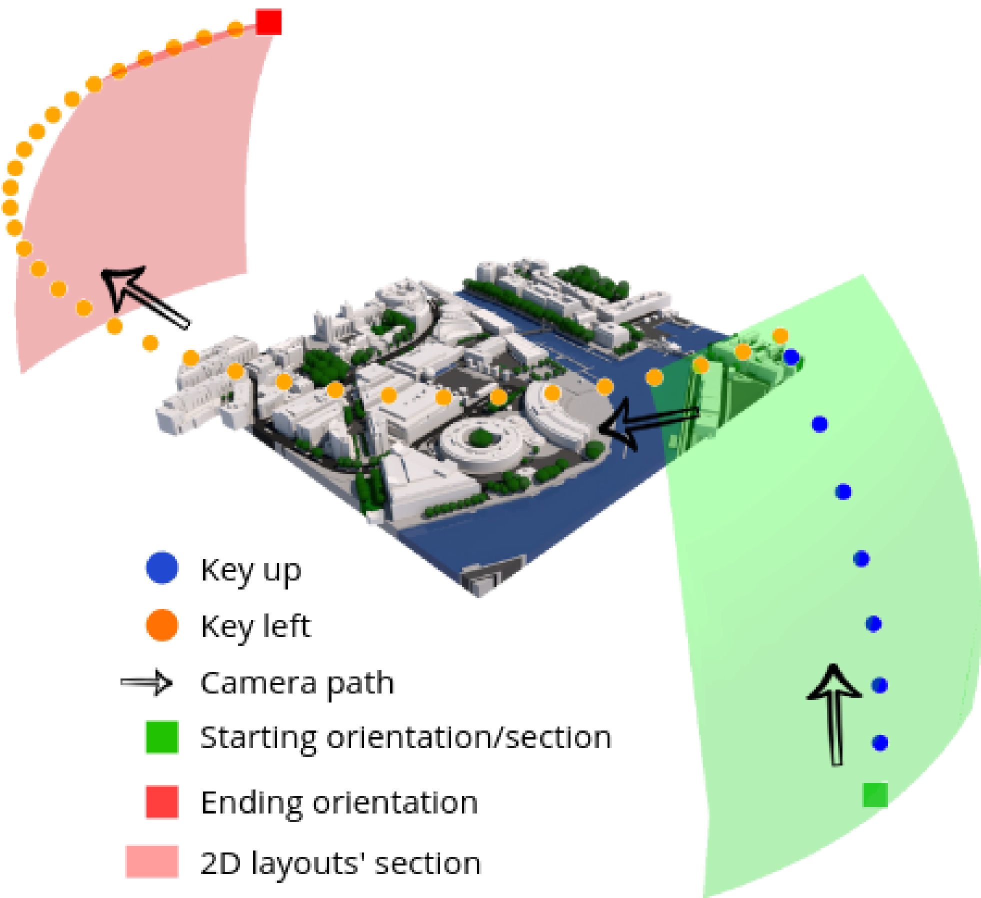

Figure 9.6. *Camera path of a specific user for a specific task. The green area represents the landing position ± 5% and the red area represents the layout orientation ± 5%.*

Fig. 9.6 displays an example of these anchor points for a specific user. This participant started at the center of the green surface, through interaction the VGE was shifted to visualize the 3D scene from a bird's-eye view, and then the scene was rotated to match the 2D layouts' orientation (represented by the red section).

The importance of the anchor points was analyzed and shown in Fig. 9.7, which depicts the proportion of the users' camera positions that are enclosed in these anchor points' sections. This proportion is calculated for all the participants. For the task *guess layout*, these two sections represent 60.8% of all the participants' interactions (34.8 for starting orientation + 26.0 for 2D layouts' orientation). For the task *guess highest*, the users performed 48% of their interactions within these sections (31.5 starting orientation + 16.53 for 2D layouts' orientation). Therefore, these two sections channel a non-negligible proportion of the users' interactions, considering the fact that these sections represent from 10% to 20% of the spherical segment (i.e., all potential camera positions), depending on their overlay. These two sections were, thus, impactful orientations for the participants.

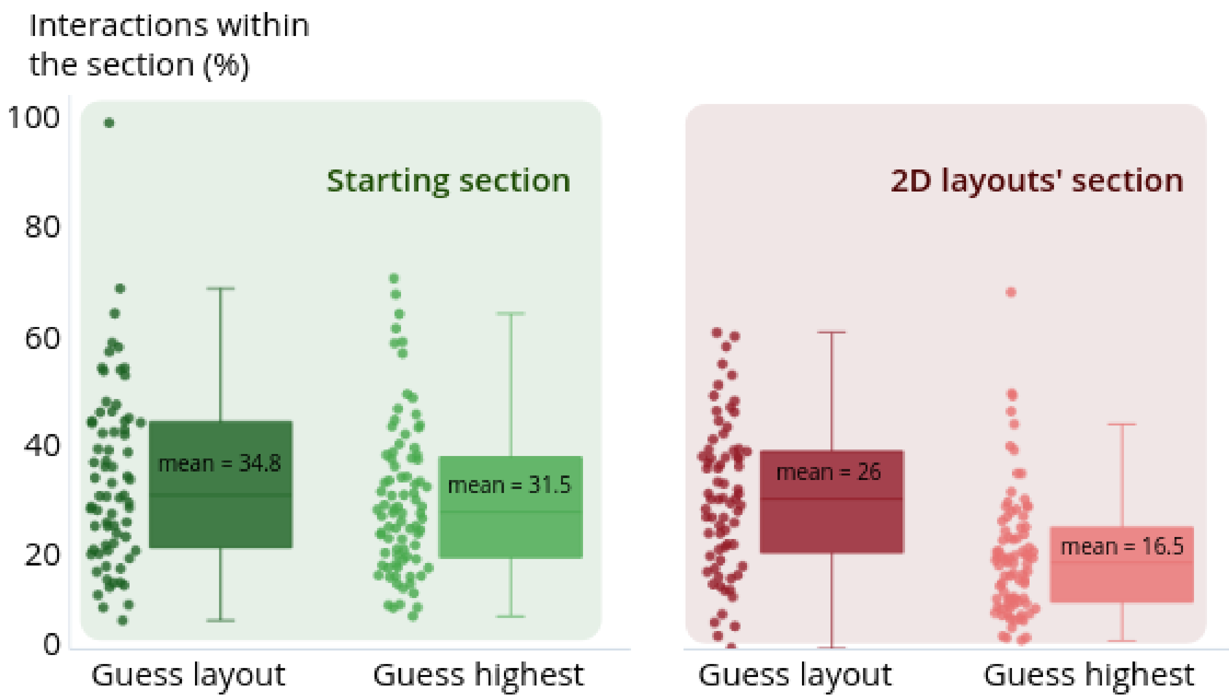

Figure 9.7. *Average proportion of users' inputs enclosed in the starting and the 2D layouts' orientation area.*

The relation between the starting and the 2D layouts' sections, as well as the camera path interpretation, are depicted in Fig. 8. For each user, all of the camera positions (for all pressed keys) were divided into five groups in chronological order (normalization of the number of inputs). The first group contains the first 20% of the positions, the second ranges from 20 to 40%, and so on. For example, if a user manipulated the camera 15 times (numbered by their chronological order), the distribution would be group *0-20%*: 1, 2, 3; group *20-40%*: 4, 5, 6; group *40-60%*: 7, 8, 9; etc. An average distance was then estimated for each group between the averaged camera positions and the two sections. The distance is defined as the yaw angle difference between the averaged camera position and the central orientation of the section. Thus, this distance ranges from 0° to 180°. Fig. 8 depicts these distances for the task *guess* *layout* of all five representations. A regression line (for the average user distance for each representation) has been calculated and drawn on the figure to highlight the global trend. The top graph in Fig. 9.8 depicts the distance compared to the 2D maps' layout orientation. We observe a diminution of the distance, i.e., participants tend to get closer to the 2D layouts' orientation processing towards the completion of their task. This relation was demonstrated statistically via a Somers' Delta estimation (δ = -.289, p-value < .001). This estimation indicates a *moderate-strong* negative correlation between the two ordinal values (groups: independent value; distance: dependent value, aggregated by 10° distance). The bottom graph in Fig. 8 illustrates an opposite relation. The distance from the origin increases over the users' inputs. A Somers' Delta value was calculated: δ = .326, p-value < .001. This calculation shows a *strong-moderate* positive correlation. Therefore, a relation can be highlighted between the two anchor points (starting position and 2D layouts' orientations). Users begin their task by exploring the 3D scene around their starting orientation and complete their assignment when attaining an orientation aligned with the 2D layouts.

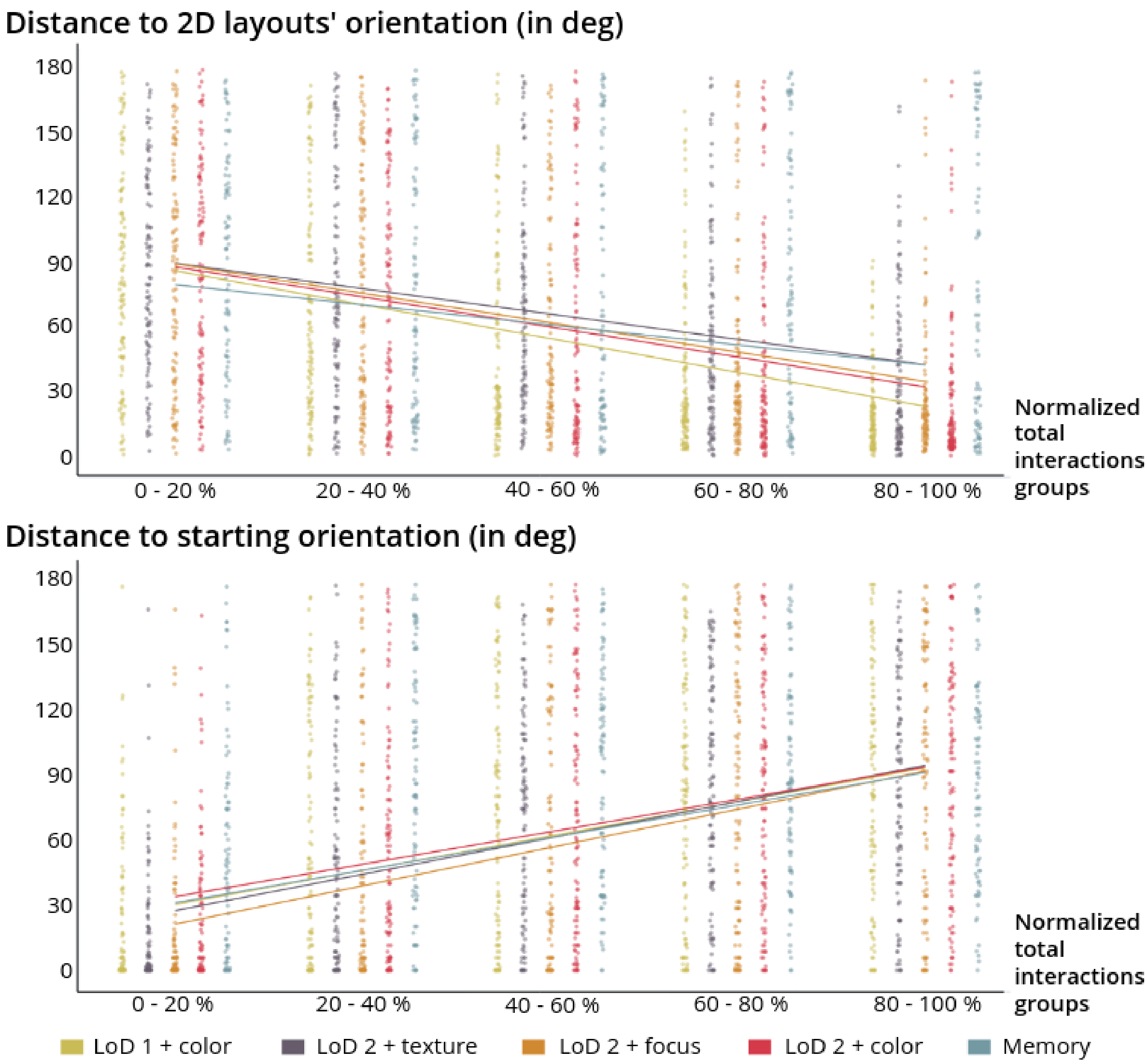

Figure 9.8. *The evolution of distance from the users' camera positions to the 2D layouts' orientation and the starting orientation at five temporal snapshots.*

9.7.4. Channeling Users' Behavior

The density of users' camera positions depicted in Fig. 9.9 provides an opportunity to evaluate how the nature of the task channels the users' behavior to a reduced set of actions. This figure presents the inputs of the participants for one full batch (*guess layout*, *guess highest*, and *guess viewpoint*) of a specific scene (*LoD 1 + color* in this particular case).

Results show that the task *guess layout* attracts camera positions on the upper part, revealing that the participants looked at the VGE from a bird's-eye view (closer to the 2D layouts). Camera's positions for the task *guess highest* are more distributed, but the bottom part is denser, indicating a view closer to the horizontal plane (which helps to distinguish the heights of the buildings). Last, the task *guess viewport* attracts the users' interactions on the two lines between the red sphere and the two different green spheres (which is needed to assess their relative visibility). These three tasks demonstrate three heterogeneous distributions of the participants' camera positions.

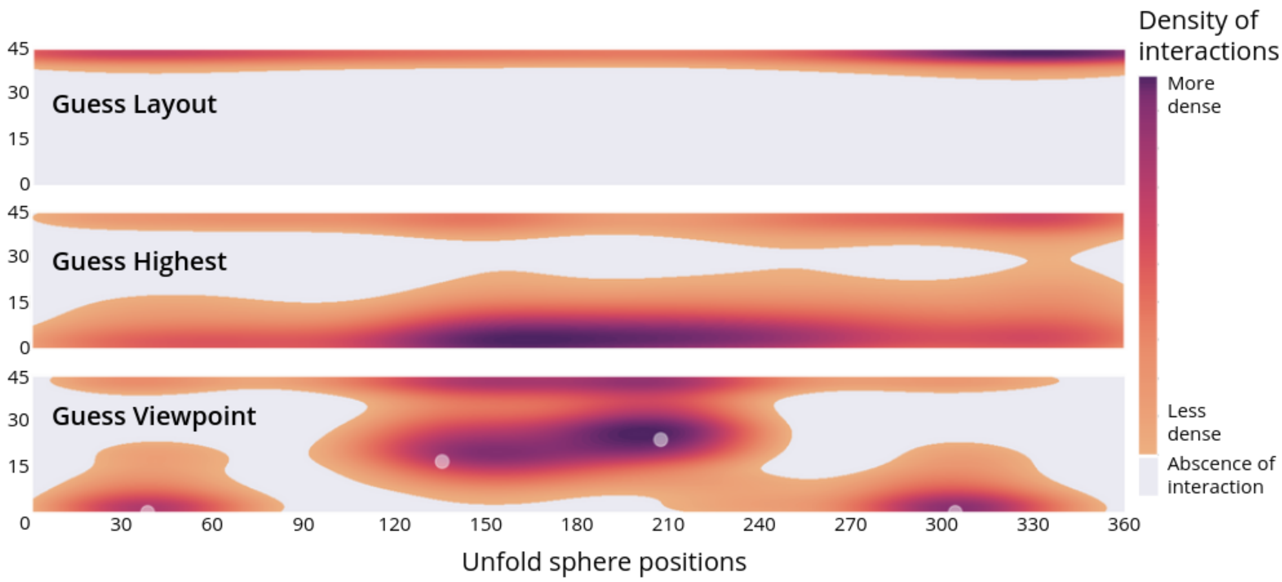

Figure 9.9. *Density of users' camera positions on the unfolded spherical segment*

A second aspect has been considered for analyzing the impact of the task on users' behavior. Participants were interacting with the VGE via a keyboard; more specifically, with their arrow keys. When starting a new step of the study, the participants discovered a task and a VGE setup; from their understanding and starting position, they instinctively decided on their first inputs. This input translates what their first intention is, which is crucial for analyzing the users' behavior.

Fig. 9.10 portrays this first intention. For the task *guess layout*, the principal input is *up* (48.2% of all first inputs), allowing visualizing the VGE from above. The second most pressing input is *down*, which represents 23.7%. For the second task *guess highest*, the number of inputs *down* becomes greater (44%) than the number of inputs *up* (36.8%).

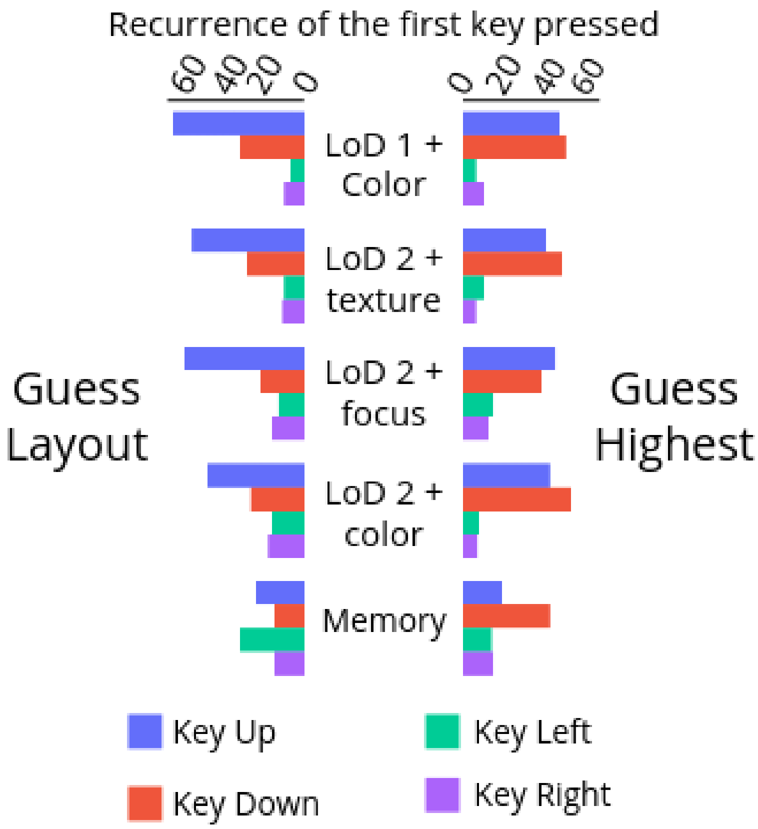

Figure 9.10. *The number of first inputs (up, down, left, right) per 3D scene*

9.8. Discussions

9.8.1. Participants Learn to Interact With the VGE

Participants executed fewer interactions to complete specific tasks over the course of the study. However, the time needed to complete the task stayed consistent. Hence, the drop in the interaction number is linked to an improvement in VGE manipulation and not to fatigue, boredom, randomness, etc. Furthermore, no significant difference in the accuracy of the answers was established[39].

Participants were discovering the layout of the various scenes through their assignments. The different scenes were off-context to avoid any recognition (that could lead to bias). Therefore, participants learned to manipulate the VGE (with its rules, tasks, and representations), in only a few interactions, notably by developing strategies to get more efficient (as soon as they start interacting with the VGE).

[39] The result on accuracy is under submission in a parallel study.

The learning process highlighted in this study is crucial for participatory approaches. Indeed, challenges faced during the first utilization of an unfamiliar VGE could be quickly overcome. Therefore, participants do not have to be trained in advance. A brief targeted tutorial explaining the VGE specificities could enhance its use by the participants, as well as improve their feedback.

9.8.2. Participant's Idiosyncrasy Contributes to Interaction Uncertainties

The ratio of the VGE's manipulation time in relation to the total time required to complete a task is strongly correlated to socio-demographic characteristics such as age or frequency of 3D use. These two characteristics are acknowledged as limiting users' performance with 3D (Stanney et al., 1998). Therefore, the ratio could predict hardship in the usage of VGE.

A ratio tending toward zero indicates a lot of pausing in the VGE interaction, possibly due to an understanding reassessment of the 3D scene and its following positions. On the opposite, a ratio close to one depicts an intensive interaction introduced by a certain proficiency in 3D. Identifying struggle or ease in interacting with VGEs should, however, not be only limited by the evaluation of this ratio. Indeed, several other parameters (spatial cognition, computing performances, screen size, disturbing factors, etc.) could have affected the users' performances and weighed in this relation between the users and the VGE. Nevertheless, the interdependence between age and frequency of 3D use did not skew the results: (1) 11 participants reported using 3D tools once a year or less frequently (5 < 32 years old and 5 > 55 years old); (2) a monthly consumption of 3D tools (considered scarce in this study) cannot reflect unfamiliarity.

Identifying struggle in manipulating VGE is central to the design of such tools for urban participatory planning. The ratio introduced in this study suggests an accurate estimation of the users' skills and is easy to evaluate in real-time. Therefore, a customized assistance could be proposed dynamically to the participants with a low ratio (defined by a threshold), to whom the VGE could offer extensive guidance. In contrast, participants with a high ratio could be offered fewer indications.

9.8.3. Participants' Cognitions Are Articulated Around the Initial Position and the Task to Complete

The analysis of the anchor points highlighted two essential positions: users' initial viewpoints and 2D map layouts. Participants remain in a section of about 10% around their initial position for about 30% of their overall positions around the scene. The same importance has also been shown for the 2D map layouts, yet the task *guess highest* reached up to about 15% of the positions.

When starting a task, the participants tend to remain in their initial position's area to frame an understanding of the scene, whereupon the next images of the scene (introduced by interaction) will be constructed. Once an overall understanding is crystallized, users explore the 3D scene to build the knowledge needed to perform the task they have to complete. In this study, the task is characterized by driving the users to align the VGE orientation with the 2D maps' layouts or by identifying the highest building. In the second task, the 2D maps' layout orientation affects the users positions less: (1) users had to identify the building that seems to be the highest, and therefore rotate the scene before locating the footprint of this building; (2) the task *guess highest* is always following the task *guess layout*, thus, the participants already have a mental image of the 2D layouts orientation and the VGE.

These two anchor positions are crucial for the design of participatory 3D tools. The initial position supports most of the users' understandings, therefore it should be selected thoughtfully, for instance, to emphasize an element within the VGE, or to have an overview of the system. The task to complete can deeply focus users' attention and either drive them to explore the environment (for example, by introducing a task on height comparison or by a sequence of tasks aiming for different localization) or to limit their displacement (via a task located at the same area of the initial position).

9.8.4. The Assigned Tasks Channel Participants' Behavior

The tasks that users have to accomplish channel the resulting interaction. The results demonstrate that the task *guess layout* focuses the interaction towards the top of the VGE, i.e., a bird's-eye-view on the scene. In contrast, the task *guess highest* drives the participant to adopt a horizontal view that is useful to identify the height of a building compared to the others. Last, the task *guess viewpoint* highly spatializes the position of the participants around the lines connecting the red sphere to the green spheres.

These interaction behaviors demonstrate the priority given by the participant to visualize the scene in a certain way to perform a task. A higher point of view close to the 2D layout, supports a global representation of the VGE, and also eases the translation between 2D and 3D representations. Other points of view encourage the distinction of heights or specific perspectives. However, the bird's-eye-view perspective appears to be central in the development of interaction behavior, where participants in addition to performing their current task anchor their VGE's mental image from this top view. Furthermore, users seem to be more comfortable with this top view, similar to a 2D map, with which they are more familiar.

Following the anchor points images for the design of VGE in urban participatory planning, the task affects the interaction behavior developed by the users. The findings of these users' camera positions support the fact that the task's configuration could drive users to broaden or centralize their cognitions within VGEs.

9.9. Conclusion and Perspectives

In this paper, we have found evidence suggesting that a better knowledge of user strategic behavior in interacting with VGEs can be beneficial for improving the design of interactive 3D tools for participatory approaches. Users' behavior was tested in an online user study that simulates specific tasks for the practice of VGE in urban participatory planning. From this experimental study, recommendations for adopting VGE in these practices were established:

- Users improve their interaction efficiency as soon as they start their tasks. Therefore, the users have a strong appropriation of the VGE. As this learning process is immediate, a specific tutorial could highly improve the handling of the interactive VGE by the users.

- The manipulation time with the 3D scene compared to the inaction time (or uncertainties) is an accurate indicator for interaction ease with VGE. This computationally inexpensive indicator could automatically be estimated during the interaction to provide users with customized guidance.

- Users fix their attention to anchor points. These positions monopolize a significant number of angles of view adopted by the users. Therefore, the cognitive load conveyed by the interaction with the VGE could be reduced by a mindful selection of the starting position within the system and consistency with the task to complete.

- The required task drives the user's interactions. Thus, the angles of view that a user adopts while interacting with a VGE can be stimulated, offering an opportunity to passively guide users. However, in these circumstances, special attention should be addressed to ethics in the system's design.

The method developed in this study for evaluating strategic behaviors of the users demonstrates its relevance. Indeed, despite the heaviness of the effort asked from users, the dropout was limited to 47% of all attempts. Following this study, an experimental comparison between a digital and a physical setup, notably with interlocking blocks, is projected to assess the impact of the digital medium on users' behavior (notably on the elderly). Furthermore, the guidelines outlined in this study will be implemented in the parallel development of a 3D platform for urban participatory planning.

This platform aims to apply these findings in a real-world context, broadening the use of VGEs in urban participatory planning, in the hope of enhancing the practices and ultimately leading to better urban decisions.

Acknowledgments

This study was partly funded by the Computers & Geosciences Research Scholarships co-sponsored by Elsevier and the International Association for Mathematical Geosciences (IAMG). The in-house code used in this study is under the MIT license available on GitHub:
https://github.com/thibaud-c/3DperceptionUX.
The VGEs are published on Zenedo, doi: 10.5281/zenodo.5137307.
We would also like to thank the participants for their generous time and valuable feedback that made this project possible.

Chapter

10. Paper F: E-Guerrilla 3D Participation: Concept, Implementation and Usability Study

List of abbreviations for the chapter:

GIS: Geographic Information Systems
ICT: Information Communication Technologies
PPGIS: Public Participation GIS
VGE: Virtual Geographic Environments
VR: Virtual Reality
UX: User Experience
URL: Uniform Resource Locator
KDE: Kernel Density Estimator
LOD: level of detail
NLP: Natural Language Processing
CGI: Computer-Generated Imagery
LIDAR: Laser Imaging Detection and Ranging
AR: Augmented Reality
VGI: Volunteered Geographic Information

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10.1. Preface

The findings of the previous chapter demonstrate that 3D mediums are complex to implement in participatory planning. The relatively limited applications of urban projects providing a 3D participatory medium are explained by the numerous use contexts, which makes their design difficult, and by the institutions that are lacking the knowledge to apply these 3D participatory tools. Furthermore, the conclusions of the previous chapters also illustrate one crucial element: most of the interactive sessions (online or in-person) endorsed by the institutions involve participants in remote locations, which is distant from the place under transformation. This disconnection leads, on the one hand, toa complexification of the understanding of the project and its impacts on the urban landscape, and on the other hand, to a compulsion of the participants to change their routine. In the case of online participation, say by using a PPGIS platform, no trigger is communicated to the participant to remind or motivate them to accomplish *their participatory duty. To reconnect the area used in an interactive context with the place affected by the project, these locations should be merged. However, in order to grant legitimate freedom to the participants the moment of the engagement should fit the routines of the participants. In this context, a full day in situ involvement of a facilitator is not practicable. A digital setting requiring participants to use their own computer equipment is similarly not likely. The only suitable device is already present in most of the participants' pockets: a smartphone. Therefore, this chapter aspires to design a modern interactive session using mobile 3D mediums that demonstrates the high potential of adopting 3D visualization to enhance the engagement of the population. A modern, practical, and realistic approach could convince the institutions to take a leap of faith in endorsing 3D participatory tools, which could be beneficial for all future participatory approaches.*

Publication and personal contributions

Chassin, T., Ingensand (2022) *E-Guerrilla 3D Participation: Concept, Implementation and Usability Study*, Front. Virtual Real. [**in revision**]

Personal contributions: formulation of research goals and aims, development and design of methodology, software development; designing web application, analyzing and synthesizing study data, figures preparation, manuscript writing.

10.2. Abstract

Typical urban participatory approaches engage citizens in-person through lengthy sessions that are located far from the area under transformation. This distance leads to issues including the mobilization of similar individuals, or overwhelming participatory codes. This study introduces a modern approach that leverages the use of 3D web applications to address some of the critical challenges of popular participatory sessions. The developed approach, named e-guerilla 3D participation, is based on five dimensions: immediate participation, easy-to-use, flexible, place-based, and immersive. A prototype complying with these five dimensions was implemented in this study. The prototype promotes an in situ engagement where all the users (without distinction) of a public area can explore a future urban project and get involved within minutes. A usability study conducted with 26 expert and non-expert participants investigated the prototype through a fictive scenario. The findings demonstrate a positive outcome in terms of participatory results that are identifiable with the prototype (highlighting the controversial elements of the projects) and encouraging feedback collected during a survey and interview. The usability study suggests key aspects that should be considered to improve the design of participatory sessions and their interactive mediums (or tool) such as realism, affordance, incentive, and purpose.

10.3. Introduction

The current practices of public participatory approaches do not meet democratic expectations; several issues are indeed inherent in the involvement of the population (Carpini et al., 2004; Healey, 1998), and the institutions are experiencing adversity facing the complexity of implementing participatory approaches (Innes & Booher, 2004). Creating an interactive space that facilitates the dialogue between the institutions and the population should provide the same engagement opportunities for all stakeholders (including individual dwellers). This opportunity is often evaluated through representativeness, which measures how well a participatory session is able to reach the full spectrum of targeted stakeholders (Rowe & Frewer, 2000). However, today's practices do not provide equal opportunities, with the design (deliberate or not) of "invited space", which benefits a few individuals (Everatt et al., 2010). Furthermore, the mechanisms of involvement often require the participants to transit to a specific location at a specific time and to remain on the site for long hours, which results in a few similar individuals attending the participatory sessions (Brown et al., 2014; Kingston et al., 2000; McLain et al., 2017), hence making the session poor in term of representativeness. As a participatory mechanism, urban participatory planning experiences similar challenges.

Digital technologies offer the opportunity to create modern virtual interactive spaces (Sinclair et al., 2017). These virtual participatory sessions, based on the use of digital Information Communication Technologies (ICT), extend the number of seats available and improve the accessibility of the sessions by providing more flexibility for the participants to choose the time of involvement (Carpini et al., 2004). Therefore, the public reached by digital participation can be broadened, which may support enhanced representativeness. In the context of urban participatory planning, the dialogue between the authorities and the public is commonly spatially anchored. To facilitate the interactions, digital cartographic mediums are adopted, notably, Geographic Information Systems (GIS) and its participatory counterpart, the Public Participation GIS (PPGIS). These systems, identified as valuable for urban planning for more than 20 years (Al-Kodmany, 1999; Peng, 2001; Rinner, 2001; Talen, 1999), are now commonly used in participatory planning (Babelon et al., 2021; Brown & Eckold, 2020; Czepkiewicz et al., 2018; Falco et al., 2019; Pánek, 2018b). However, these solutions do not appear completely representative or inclusive (Kahila-Tani et al., 2019; Sieber et al., 2016) and similar participant profiles are again identified (Brown, 2012; McLain et al., 2017). Participants remain indeed difficult to motivate in attending participatory sessions, even with digital tools (Münster et al., 2017). The key to increasing engagement is to design participatory e-tools that are easy-to-use, perceived as useful, plug-and-play, and user-centered (Bugs et al., 2010; Steiniger et al., 2016)

The cartographic medium as a visual material can stimulate the dialogue between stakeholders, especially by creating a common language that could be understood and used by individuals from different backgrounds (Metze, 2020; Roque de Oliveira & Partidário, 2020). However, the 2D cartographic object does not straightforwardly portray the height parameter, which could lead to legibility challenges (hence, not in line with the role of visual materials). The depiction of the height is nonetheless crucial for urban planning, where the debate frequently focuses on the height of new volumes (Ruming, 2018; Ruming et al., 2012). The third dimension offers a clear representation of urban and natural landscapes, which facilitates the understanding of complex spatial aspects (Al-Kodmany, 2001; Schroth et al., 2011), that are often inherent to urban projects. For more than 20 years, the development of Virtual Geographic Environments (VGE) has enhanced the 2D cartographic visualization and manipulation of advanced geographic data (supported by the GIS) via the integration of the 3D, and its z component (Batty, 1997; Lin et al., 2022; Lin & Gong, 2001). VGE and 3D visualization are flexible in terms of data (incorporation of various sources), representations (from abstract to realism), and interactions (from navigation to design) (Christophe, 2020; Çöltekin et al., 2016). This versatility offers the ability to adapt the VGE settings to fit the participatory tasks, for instance with different representations to stimulate the collection of information, but more importantly, it appears motivating for the participants (Hayek, 2011). Nonetheless, the consumption and manipulation of 3D mediums can be troublesome for certain individuals, hence leading to inequalities that are stimulated by socio-demographic characteristics (Burigat & Chittaro, 2007; Chassin et al., 2022; Lokka et al., 2018).

However, most of the applications of PPGIS and VGE in urban participatory planning, even if web-based, are optimized for personal computers. Hence, participants are still restricted in the modality of engagement. The necessity to be involved from a personal computer limits the freedom of the dwellers to participate *on the go*, but this unrestricted participation is supported by their smartphones (Ertiö, 2015). Moreover, mobile-enabled participation using VGE and web browsing can be conducted “out of the lab” (Gill & Lange, 2015). Outdoor mobile participation has several advantages. First, it enables the participants to choose the modality of their engagement in terms of time and location (Ertiö, 2015). Second, regarding the digital divide, it seems that disadvantaged communities favorize mobile-based broadband (Mossberger & Tolbert, 2021). Therefore, mobile-enabled participation could be a valuable alternative to enhance the representativeness and inclusivity of participatory sessions. Third, it can anchor participation *in situ* (Bohøj et al., 2011). Most of the participatory sessions are located in a remote location that is by definition not situated in the area that is impacted by the project. Adopting mobile-enabled participation could, therefore, reconnect the participation with the area under transformation, facilitating the understanding and assessment of the impact of the urban project. Moreover, the participatory session could be available for all users of public spaces, including day workers and tourists, which are often forgotten by participatory approaches. Non-local citizens can indeed provide valuable inputs in participatory planning (Onitsuka et al., 2018). Some positive applications of *in situ* participation are mentioned in the literature, including the use of a mixed reality table and 3D mock-ups in a tent (Basile & Terrin, 2010), the design of a head-mounted Virtual Reality (VR) setting, or the adoption of mobile Augmented Reality (Korn, 2013).

This study aspires to introduce a new approach to participatory planning, namely e-Guerrilla 3D participation, which considers current participatory challenges and creates mechanisms to tackle them. This approach develops the concept of *in situ* engagement through the use of a VGE and brief semi-immersive participatory tasks. One of the key objectives of the approach is to improve the inclusivity of participatory planning by implementing a 3D innovative design for quick, simple, and efficient engagement. This article will first present in detail a definition of e-Guerrilla 3D participation and its dimensions. Then, the technical implementation of the approach will be demonstrated. To challenge the prototype in real conditions, we, then, conducted a usability study (N=26) with experts and non-experts, which tested the prototype through a scenario. Last, we describe findings that are remobilized to discuss the future of urban participatory e-planning.

10.4. E-Guerrilla 3D Participation Approach

The approach of 3D guerrilla e-participation combines several methods from diverse fields. First, the term *guerrilla* originates from User Experience (UX) usability testing (Nielsen, 1994). Their goal is to reduce costs (financial and temporal) related to usability engineering methods, hence, limiting the “intimidation barrier" of using these approaches. The guerrilla approaches have several settings, one of the most famous examples is a UX designer waiting in a coffee shop with a sign mentioning "Ask me about a free coffee". When testers/participants inquire about the coffee, the UX designer explains that the testers/participants can enjoy a free drink if for a few minutes (time to drink a coffee) they test a product and answer a few questions. This method can be very efficient because: (1) it uses a strong incentive (a free coffee) to attract testers/participants; (2) it is low-cost compared to other types of testing; (3) it is engaging the testers/participants where they already are (no change of routine); and (4) it is simple to implement and can be set up hypothetically anywhere in a few minutes. These guerrilla approaches are often referred to as "quick and dirty" methods to collect user feedback, but can still provide valuable information (Diederichs et al., 2020; Lallemand & Gronier, 2018). The term "dirty" implies that the testers/participants are often not representatives of the profile of the target users. Based on this guerrilla concept, the finished company HappyOrNot (happy-or-not.com/en/) designed the well-known solution consisting of four smileys (very happy, happy, unhappy, very unhappy) that aims at gathering feedback from customers right after experiencing a service (often seen in airports, shops, etc.) (Figure 10.1). This solution provides the customers the opportunity to deliver *in situ* immediate feedback. The presence of the colored smileys and the opportunity to participate easily without engaging any time works as the right trigger to encourage customers to click on one of the buttons. This type of participation appears to be efficient and inclusive (lowering the language barriers) (Jory et al., 2014; Morgan-Daniel et al., 2021).

Figure 10.1. *An example of the guerilla solution design by HappyOrNot*

Second, our approach to guerrilla e-participation borrows mechanisms from tactical urbanism (Lydon & Garcia, 2015). Tactical urbanism describes low-cost, ephemeral actions on the territory that aims at delivering long-term transformation of the place (physical and/or social). These actions can be initiated by a bottom-up but also by a top-down process. The installation of benches and tables along the street, the creation of urban gardens, or the drawing of new street signage are a few examples of tactical urbanism (Cariello et al., 2021; Lak & Zarezadeh Kheibari, 2020). Therefore, the actions produced within the scope of tactical urbanism are diverse, *in situ* (i.e., contained in the territory under transformation), anchored to a small scale, engaging for local communities (i.e., participatory), and often articulated around creative activities such as art (Courage, 2013). Tactical urbanism immerses local communities in an experimental setting of the place, which generates an authentic emotional response that could be investigated by practitioners (Stevens et al., 2021) to plan the evolution of the city in compliance with the urban dwellers' needs (Silva, 2016).

Built on these concepts and examples, our approach to guerrilla 3D e-participation is based on the design of a digital participatory approach that uses 3D to support a better immersion of the participants/users in an alternative scenario of a place. Guerilla usability testing and tactical urbanism both promote a method that should be flexible, informal, out-of-the-box, time-bounded, and proximate to participants. From these basic requirements, guerilla testing often implies a simple but efficient way to collect information. The HappyOrNot approach is an excellent example with the extensive number of quantitative data produced by one-click feedback. A similar aspect of both the HappyOrNot and tactical urbanism approaches is the collection of participants' contributions *in situ*, i.e., where participants are experiencing the stimulus (which is the transformation of an area in urban planning).

Therefore, our approach to e-guerrilla 3D participation aims at mobilizing mechanisms of guerrilla usability testing and tactical urbanism through five dimensions:

- ***Immediate participation***. The participatory task should be accessible immediately without any delay, hence, the entry cost has to be actively reduced, to create a sentiment of plug-and-play. Moreover, the approach should respect and value the time offered by the participants that have busy routines, thus, the nature of the task to accomplish should be quick to execute, but meaningful.

- ***Easy-to-use***. Increased complexity may drive users/participants to abandon their tasks, which leads to excluding some individuals, and ultimately hindering inclusivity. Therefore, the approach should promote a user-friendly, seamless experience that could increase the engagement of users/participants.

- ***Flexible***. Urban projects and participatory sessions are heavily heterogeneous, e-guerrilla 3D participation should be able to comply with these diverse contexts and applications.

- ***Place-based***. Participatory tasks should be performed *in situ*. The objective is to create a strong connection between participants' contributions and the place under transformation. The place related to the project is emotionally bound to its users, therefore, enclosing the participatory interaction within the place under transformation could create more meaningful contributions. Moreover, the users of the place are not only the public identified and invited by the authorities; the involvement *in situ* could facilitate the participation of all the users of a place.

- **Immersive**. Urban projects are complex to understand due to their uncertainties. Immersivity can promote a direct engagement via portraying, without artifice, the future project within its surroundings, hence facilitating the comprehension of the project.

10.5. Implementation

Based on the concept of e-guerrilla 3D participation, we developed a prototype implementing the five dimensions: immediate participation, easy-to-use, flexible, place-based, and immersive (Figure 10.2). This section does not aspire to convey too many technical details; we will present how the five dimensions were translated into a prototype. With this demonstration, we expect to provide a factual description of the choices that were made (technical, design, functionality, etc.) in order to facilitate the understanding of the e-guerrilla 3D participation and stimulate the creation of future alternative implementations. Three subsections will discuss technological choices, controls, and participatory tasks.

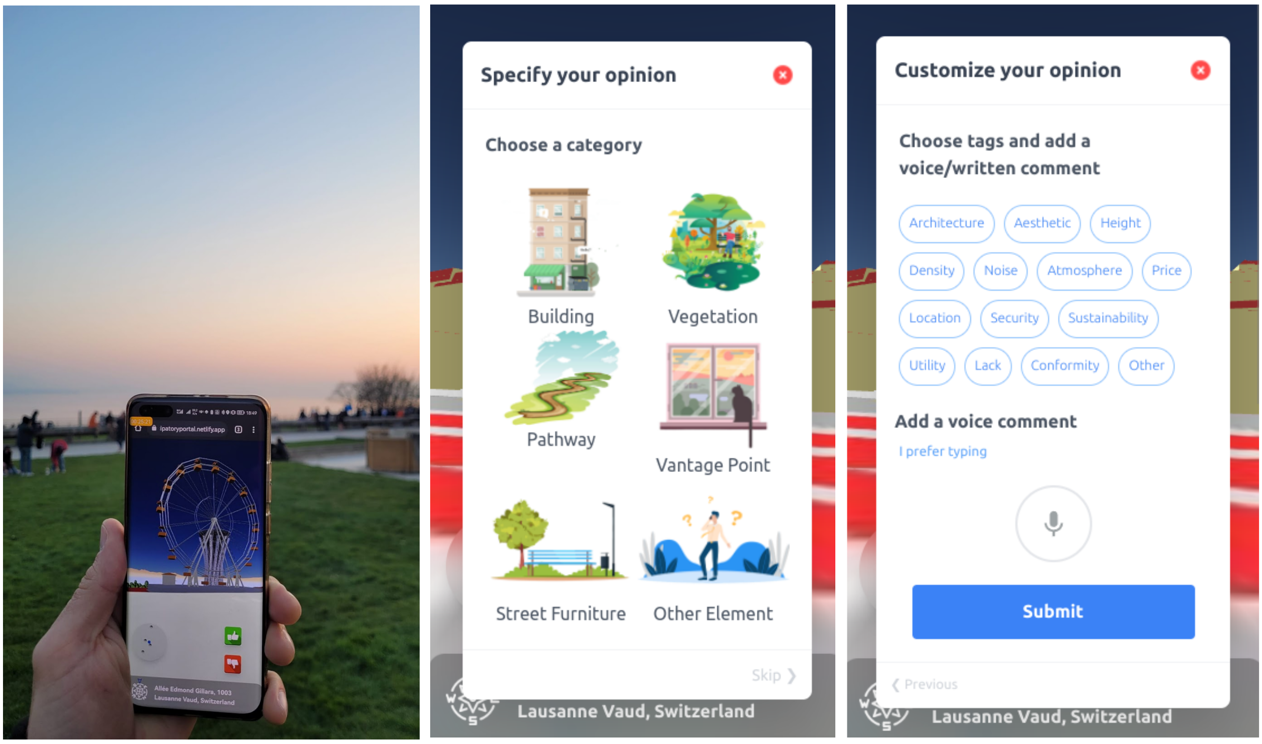

Figure 10.2. *Presentation of the screen of the web application implementing the concept of guerrilla e-participation. From left to right: a picture of a participant using the app in situ and observing the current layout of the public space with the future project; first screen where the participants have to choose a category for their positive/negative tagged object; second screen where participants can develop their observation with tags and comments before submitting*

10.5.1. Technology

One of the requirements is that the prototype allows *in situ* participation. Furthermore, to improve the freedom of the participant, the time of the engagement is not bounded. This condition implies that urban dwellers should be able to visit the place under discussion at any time and be autonomous while contributing to the project. Therefore, no specific devices operated by a facilitator, which would be available for only a few hours, can be implemented. Also, to comply with the easy-to-use dimension, we design the prototype to be run directly in a browser from any smartphone. Today, smartphones are widely adopted and used by the population over the globe and currently represent 60% of the market share (StatCounter, 2022).

The adoption of web technology aims at promoting access to e-tools everywhere without any download (perceived by the consumers). Therefore, the prototype could be immediately available by addressing an URL (Uniform Resource Locator) within any browser. This URL can be typed manually, hence, increasing the time before starting to participate or the URL can be accessed from a QR code (quick response code), which provides immediate access to the participatory task. Furthermore, the adoption of QR codes has been extensively used during the COVID-19 pandemic, which implies that the population is now accustomed to scanning these types of codes.

The web application was based on a virtual globe (to enable 3D), namely CesiumJS (cesium.com), which is already known and used in the scientific community (Lafrance et al., 2019; Virtanen et al., 2018; Würstle et al., 2021). Virtual globes are powerful tools that can render large areas as well as small ones. Since 1998 and the speech of former Vice President of the United States Al Gore about *digital earth (Gore, 1998)*, the development of the virtual globe has been thriving (Keysers, 2015). We selected CesiumJS, because the library is open source, highly flexible, provides numerous out-of-the-box functionalities, and is often updated. Furthermore, compared to other web solutions (video games engine, proprietary software, other libraries), CesiumJS supports natively geospatial data and is able to tile large datasets to render them seamlessly (Krämer & Gutbell, 2015). Another reason that motivated our choice to adopt a virtual globe, is the availability of basic data (digital elevation model, satellite imagery) throughout the entire Earth's surface. Therefore, our prototype may be easily re-implemented for other projects in different locations. Regarding the data, we used the 3D building layer provided in open data by Swisstopo (swisstopo.admin.ch), which contains the entire set of buildings in LOD2 (level of detail) for all of Switzerland. For projects outside Switzerland that do not have access to this qualitative open data, since the 1st of June 2020, CesiumJS has integrated out-of-the-box OpenStreetMap Buildings (osmbuildings.org), which cover nearly the entire globe (Ring, 2020).

Immersive technologies such as augmented and virtual reality with smartphones or head-mounted devices have not been selected for our prototype. The immersive feeling promoted by virtual reality technologies can be valuable, however, the necessity of using a device (headset or cardboard) that immerses the participants completely is less appealing. Some studies have shown that real-world stimuli (i.e., being *in situ*) could provide some opportunities for immersive virtual reality (Pouke et al., 2019), nonetheless, the use of a screen that completely obliterates the real-world view is not desirable (and impracticable) for our approach. Relocating the participation *in situ* aims at promoting an association between the real-world and virtual objects to facilitate the comprehension of the aspects of the project that transform the place. Augmented reality, closer to the real environment in the reality-virtuality continuum (Milgram et al., 1995), can promote flawlessly the association between the real and virtual world and enable public participation (Hunter et al., 2021). Furthermore, democratized by the popularity of Pokemon GO (pokemongolive.com), the technology of Niantic (nianticlabs.com) supports the integration of virtual objects in the real-world without requiring embedded LIDAR (laser imaging detection and ranging) technologies. Therefore, any smartphone has access to augmented reality functionality using a basic camera (i.e., more inclusivity). However, the technology provides only a non-permanent environment, and geo-location is not captured, which is a major issue for adopting this technology to our approach.

10.5.2. Controls

The e-guerrilla 3D participation approach emphasizes the requirement of inclusivity in participatory planning. However, the manipulation and perception of a virtual geographic environment, such as a virtual globe, can be challenging for several users/participants according to their skills, socio-demographic characteristics, background, and experiences (Chassin et al., 2022; Çöltekin et al., 2016; Ugwitz et al., 2019). Considering these differences, we aimed at lowering the interaction metaphors with the virtual globe to create better affordances, thus facilitating the interaction (easy-to-use dimension). Typical interactions with virtual globes are executed through a mouse and keyboard or a touch-screen (for smartphones). The approach of e-guerrilla 3D participation is immersing participants directly within the location of the project under discussion, hence, the mouse and keyboard are not straightforwardly practicable (because the participants would have to stay static or transport the mouse/keyboard/device at any time). Touch-screen-based manipulation can also hinder the association between real and virtual, with participants looking down at their phone to observe and interact with the VGE, and then looking up to observe the urban landscape, which could result in participants being mainly focused on their screen, as observed with pupils (Ingensand et al., 2018). Furthermore, touch-screen-based interactions have issues related to the occlusion of the elements that are visualized by the fingers of the user (Wobbrock et al., 2008).

Our approach to facilitating the interaction between the users/participants and the virtual globe is to mobilize the sensors accessible within the smartphone (GPS, accelerometer, orientation angles). This data from phone sensors has already been proven accurate enough in studies using pictures taken from smartphones (hence, containing default sensor data) and published on social networks (Chassin & Ingensand, 2021; Foltête et al., 2020). The smartphone could, therefore, be used as a tangible device to manipulate the virtual globe; the use of tangible devices has demonstrated a certain value compared to the more typical techniques of interactions (touch-screen, mouse/keyboard) (Besançon et al., 2017). This sensor data is becoming increasingly available through web browsers with the development of Sensor APIs (Application Programming Interface). With this data, it is possible to locate and orient the smartphone of a participant in real space. Considering that a virtual globe portrays a virtual image of the real-world, we can, therefore, connect the real data provided within the smartphone to the virtual environment. Our controls of the virtual globe were thus reduced to moving physically within the real-world, and orienting the smartphone in the desired direction. Users/participants are able to visualize through their smartphone a virtual overlay (future project) on the real-world such as a portal or a window (Figure 10.2). Therefore, no direct interaction was necessary to manipulate and orient the virtual globe, which contributes to lowering the entry cost of the approach, therefore improving its inclusivity.

10.5.3. Participatory Functionality

With the e-guerrilla 3D participation approach, participants are involved *in situ*, directly within the place under negotiation, which is also the living environment that they practice. Therefore, participants are already familiar with the virtual space, because it is identical. The contextual objects, meaning the buildings, are all abstractly represented in the virtual environment which is overlaying the real environment; therefore, the participants should be able to connect these two spaces easily and focus on their participatory tasks.

In the prototype that was implemented, we aimed at collecting the participants' opinions about a hypothetical future layout of a public place. We adopted a mechanism broadly used in Public Participatory Geographic Information Systems in a 2D layout (e.g., Brown & Eckold, 2020; Bugs & Kyttä, 2019; Haklay et al., 2018; Sieber, 2006), which aimed at collecting place-based inputs from the population about specific topics (such as security, future development, or like/dislike) through GIS functionality and vector data. In the approach embodied by the prototype, geo-located positive or negative opinions were gathered in a semi-immersive environment. To mark a geo-opinion, the participants could look at any virtual object and select an opinion.

Participants had access (at any time within the web application) to two participatory options (positive: 👍 and negative: 👎). The selection of one of the two options led to two additional steps (Figure 10.2), which are independent of the selected options. The first step is an optional category selection that encourages participants to define the object under discussion (i.e., linked to the positive/negative opinion). The categories were: a building, vegetation (trees, bushes, plants), a pathway (street, walk path, sidewalk, etc.), a vantage point, urban furniture (benches, public trash, light pole, etc.), other elements (that do not fit any category). The selection of the category was facilitated by the depiction of generic images supporting the participants in the selection of the right category. The second step, also optional, offers participants more freedom to define their opinion. Participants in this last step could select tags connected to their opinion and category and add written or vocal comments. Vocal comments were encouraged because besides being simple and quick to generate for any participant (no typing is involved), the voice can be recorded, hence providing additional valuable information about the participants (age, sex, emotion, etc.), that can be automatically recovered with a satisfactory accuracy (Zaman et al., 2021).
Saved in a database, each participant's contributions (opinion, category, tag(s), vocal and written comments) were associated with the sensor data recorded at the time of the contribution (GPS position, orientation of the mobile phone).

The participatory task was implemented for the case study that will be presented in the next section, however, with the flexibility provided by web applications and virtual globes, other participatory tasks can be implemented as well, to fit the use context in which the approach of e-guerrilla 3D participation would be applied.

10.6. Usability Study

The evaluation of the usability of a new technological tool is complex and often overlooked. This study aimed at challenging our approach with participants (expert and non-expert) through a fictive scenario in a real location. Participants (N=26) were invited to give their opinion on a park's new layout. Through the usability study, we gathered technical and conceptual feedback to test the validity of our approach/prototype in a real practice exercise and identify improvement outlooks.

10.6.1. Designed Use Case and Study Area

The scenario designed for the usability study was fictive but realistic enough to convince the participants of its validity. As the study area, we selected an urban green space, located in Lausanne, Switzerland, and presented in Figure 10.3. This urban green space was appropriate for the conduction of the experiment, because this public space is mostly bare, with a large grass surface, and contains only a few pieces of urban furniture. The place overlooks an open space, where a lake and mountains are clearly visible. However, because of its relative bareness, it is not very popular. Therefore, this urban green space is suitable for the conduction of our usability study: (1) the place is located in the open air without many trees which is beneficial for the use of the GPS sensor of the phone; (2) the place is not cluttered by too many objects (urban furniture), which should be model in the VGE or could complexify the scenario (with the additional virtual objects); and (3) the breathtaking view can be obstructed to stimulate the participants' feedback.

The markers, shown in Figure 10.3, portray the location of the additional objects that have been effectively implemented in the scenario: [0] (green) indicates the starting point, [1a] and [1b] the implementation of two benches, [2] the replacement of a restaurant by a famous American coffeehouse, [3] a substantial Ferris wheel, and [4] a skyscraper. The fictive transformations created by the projects were consciously controversial to stimulate participants' divided opinions. For instance, the addition of a coffee house could contribute to enhancing the place, however, we selected an American brand known to be polarizing.

We are convinced of the unrealistic nature of this fictive project. The scope of the project under discussion is too large and if the population is consulted at any point of an urban project; it would be on a reduced range of objects. However, the goal of our study was to assess the performance of the prototype and collect participants' tangible feedback on the approach.

Figure 10.3*. Illustration of the study area with the location of the project's objects. The top view of the study area shows a lighter surface, which represents the explorable area during the usability study. On the right, the study area is presented from a first-person perspective with a realistic view (right-top) and a view from the VGE (right-bottom)*

10.6.2. Procedure

Figure 10.4 presents the procedure of the usability study. Two entries are present in the figure: on the left are the steps that were executed during the experiment, and on the right is the expected practice of the approach/prototype without a facilitator. The usability study of 30 min was conducted with one participant at a time. In the expected practice, several participants can be involved at the same time, and the time of engagement lasts only a few minutes.

The usability study started by welcoming the participant, explaining the program of the experiment, highlighting the fictive aspects of the scenario, presenting a 2D paper-based map of the fictive project, and explaining the operation of the prototype. Each of the project's objects was explained one by one and their orientation in the real place was shown. The explanations were emphasized by contextual details and comments on the philosophy of each transformation induced by the project. For instance, the conversion of the restaurant into a coffee house was imagined to support the lack of takeaway offerings in the area (contributing to the non-popularity of the place). Furthermore, information about the fictive participatory session was also shared with the participants. We envisioned the participatory session taking place after a designed phase conducted by urban experts and the project leaders. The project was ready to be submitted to the legal public inquiry (where the population can legally oppose the project), but the municipality fictitiously requested this participatory session to assess the population preferences and measure possible opposition.

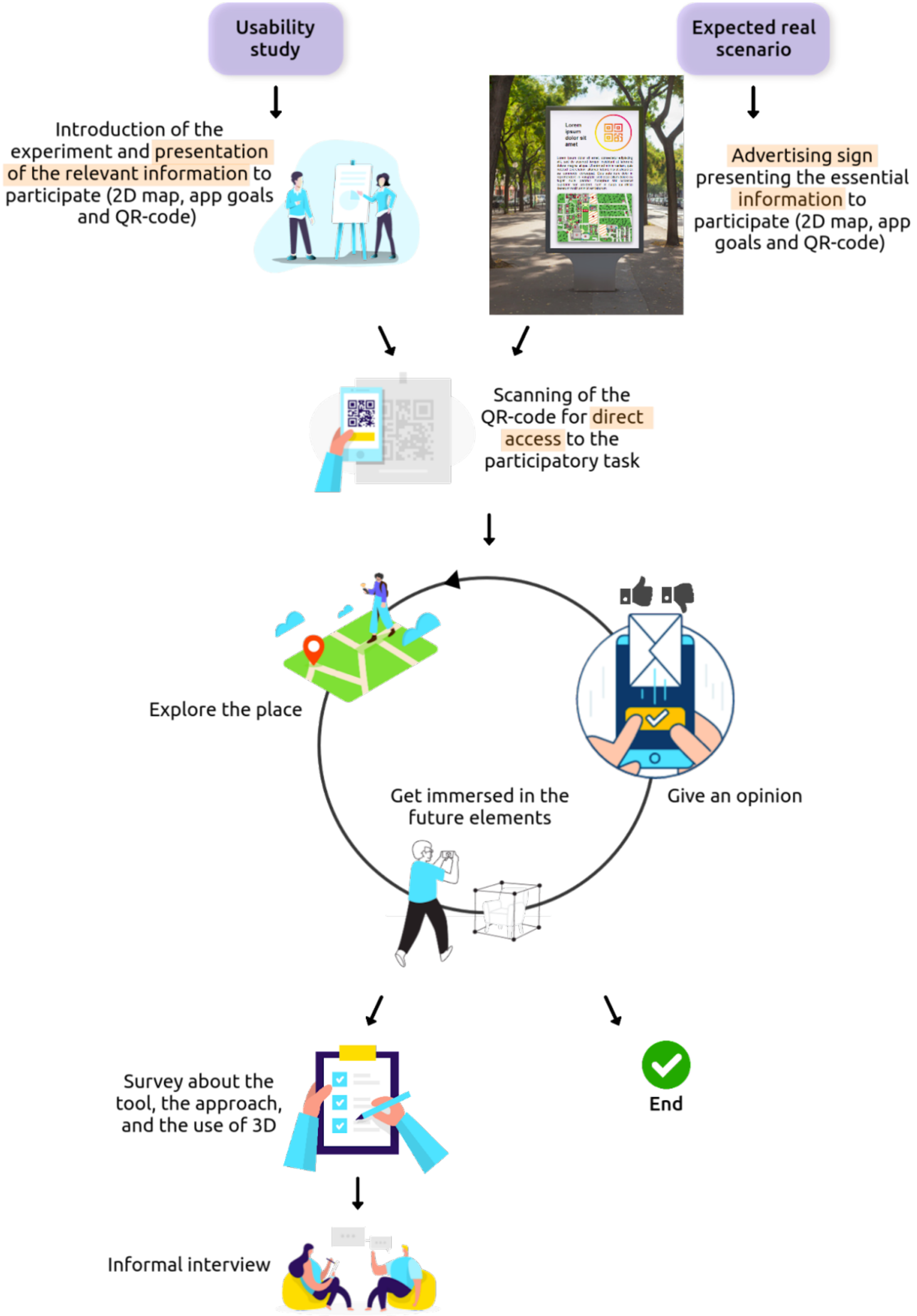

Figure 10.4. *The procedure of the usability study. The left track shows the step of the experiments between a facilitator/observer and the participants. The right track portrays the expected practice of the approach/prototype*

Participants were also informed how the collected contributions will be considered. In the real expected practice, an information sign containing a QR code would describe this information. Then, the participant scanned a QR code to access the prototype. No download was required, but two authorizations were requested from the participants: access to the GPS position and access to the microphone of the phone (to be able to leave vocal comments). The experiment was conducted on a unique phone to standardize the contributions of the participants. The participants were then free to explore the future project with the prototype, get immersed in the new layout, and record contributions. An observer was shadowing the participant to make sure that the prototype was used as expected and to record any difficulties in conducting the participatory tasks.

After this step, the expected practice of a few minutes is completed. In the usability study, the feedback of the participants was collected through an online survey and was followed by a brief informal interview.

10.6.3. Participants

The usability study concerned 26 participants, who were invited to participate from March 22 to April 27, 2022. Nearly 40% of the mobilized participants were female. Young and elderly were involved in the usability study, however, the median age is relatively young. More than 90% of the participants have a university degree. They mostly evaluate themselves to be confident with the use of digital and 3D tools but consider their knowledge of urban planning practices insufficient. Moreover, most of the participants declare having never attended participatory sessions. The majority of the participants have a smartphone that has less than two years old that they often use in the street (84.6%). Furthermore, they do not appear to frequently visit the study urban. Table 10.1 summarizes the socio-demographic information of the participants collected during the online survey following the usability study. Six professionals (i.e., experts) also participated in the study, we were able to invite two professionals of participatory approaches, one former municipal director of an urban planning department, a project manager in a GIS department, and two urban planning consultants.

The profile of the non-expert participants is fitting our approach/prototype. These participants are indeed tech-savvy and young but seem to be foreign to participatory approaches. Our approach/prototype aims at improving the inclusivity of participatory approaches, i.e., mobilizing the “silent majority”, with a technological approach. Therefore, the participants engaged in this usability study appear to be one of the public that our approach/prototype could encourage to be more involved in urban participatory planning.
The socio-demographic characteristics described in this section are collected from the survey that followed the experiment conducted with the prototype. This information is not available within the prototype or its resulting output.

Characteristics		*N=26(%)*	*Median(sd)*	
Gender				
	Male	16 (61.5)		
	Female	10 (38.5)		
Age			35.73 (11.25)	
Education				
	at least a Bachelor's degree	24 (92.3)		
	Professional school	2 (7.7)		
Skills		*Insufficient*	*Moderate*	*Sufficient*
Digital		0 (0)	3 (11.5)	23 (88.5)
3D		1 (3.8)	5 (19.2)	20 (76.9)
Urban planning		13 (50)	5 (19.2)	8 (35.8)

Table 10.1. *Distribution of the socio-demographic characteristics of the 26 participants*

10.7. Findings

The findings demonstrated in this study have two objectives. The first objective is to assess the quality of the output provided by the prototype, i.e., which results can be the output from the concept of guerilla 3D e-participation. This analysis will be conducted through a kernel density estimator and the identification of the objects discussed by the participants. Several additional investigations on the collected data are possible, however, these prospects of data exploration will only be described and not fully tackled because, on the one hand, we would like to focus more on the second objective, and on the other hand, the project under discussion is entirely fictive. The second objective is to evaluate the quality of the prototype and the user experience (positive or not) while iterating with the prototype. Hence, through the findings, we will develop two outlooks, one about participatory planning practices with the introduction of the concept and one more technical about the prototype itself.

10.7.1. Participants' Contributions Analysis

Through this study we reached 26 participants, including 6 experts. The participants contributed with 150 data opinion points, which represent on average 5.8 contributions per participant. Therefore, participants share more opinions than the number of project elements (5). Of these 150 contributions, 28% contain written comments shared by the participant, and 21% of vocal comments. The contributions were mostly positive (60% were positive and 40% were negative). Furthermore, the written and the vocal comments were converted in length (number of words and seconds) to assess if a relationship between the length of the comment that is positively or negatively tagged could be identified. However, the results were evaluated with a Wilcoxon rank-sum statistical test, and output negative results for both ($p > .05$ for vocals, and $p = 0.054$ for written).

10.7.1.1. Kernel Density Estimator

To investigate the appreciation of the future project by urban dwellers, we analyzed the spatial distribution of participants' contributions (positive and negative). Figure 10.5 depicts the Kernel Density Estimator (KDE) of these opinions. Distributed between the positive and negative KDE, we observe three main kernels, which describe areas that have collected the most contributions. Figures 10.5a and 10.5b highlight one kernel (close to object 1a) that is positioned at the same location for the negative and positive contributions. A shared kernel indicates a controversial area, where the participants are vividly engaged with the project elements situated in this area. Moreover, the two additional distinct kernels indicate an area where the participants seem to agree on the positivity (close to object 1b) or negativity (close to object 3 facing object 4) of the object observed at these locations. Therefore, the two areas where participants appear to share an alike perception of the project's elements do not need further discussion, because the participants have a clear standpoint. However, for the identified share kernel, this area should be further discussed in additional participatory sessions, through an extended engagement in order to understand the causes of this divergence.

Figure 10.5. *Kernel Density Estimator of the positive (A) and negative (B) contributions recorded by the participants. The points 0, 1a, 1b, 2, 3, and 4 represent the objects of the project described in Figure 10.3*

10.7.1.2. Interpreting the Contributions

Participants are able to record a positive or a negative contribution through the prototype at any time during their immersion in the future project. All the contributions are stored in a database with the GPS position and the orientation angles of the smartphone, however, the object targeted by the participant is not documented. This free engagement has three advantages: more flexibility in the prototype implementation (that is not affected by the project and its object under discussion), the reduced time needed to contribute (no additional step to record the object), and the ability to engage the discussion with elements that are not present within the project (for instance, it is possible to mark an empty location as negative to indicate the lack of trees or benches).

However, this approach implies that the targeted objects by the participants are not straightforwardly identifiable, hence, requiring the development of a post-processing operation to label the targeted objects. These operations are described in Figure 10.6c. From the stored GPS position and orientation of the smartphone, we can create a vector (its length is defined as greater than the study area). This vector will be used at the height of an isosceles triangle, which is constructed around the vector with a short base. The triangle is then checked for any project objects enclosed on its surface. If no objects are identified, the base of the triangle is increasingly extended, until an object is detected. A maximum triangle base has also been defined to be able to detect a contribution that was not aimed at any object. The raw orientations of all the positive (blue) and negative (red) contributions are shown in Figure 10.6a. We can observe that contributions have a clear orientation toward the objects of the project and that it would have been possible to identify the approximate position of the objects straightforwardly for the orientations. Figure 10.6b illustrates a positive/negative distribution of the identified objects through the method presented in Figure 10.6c. Only three contributions were not targeting a project object. With the identification of the objects, we observe that bench 1b has been significantly valued by the participants. The other objects demonstrate fewer differences between the positive or negative appreciations. Only the Ferris wheel (3) was considered a negative element of the project. However, because of the small differences in the participant opinion, objects 1a (bench), 2 (coffee house), 3 (Ferris wheel), and 4 (tower) could be discussed further through additional participatory sessions.

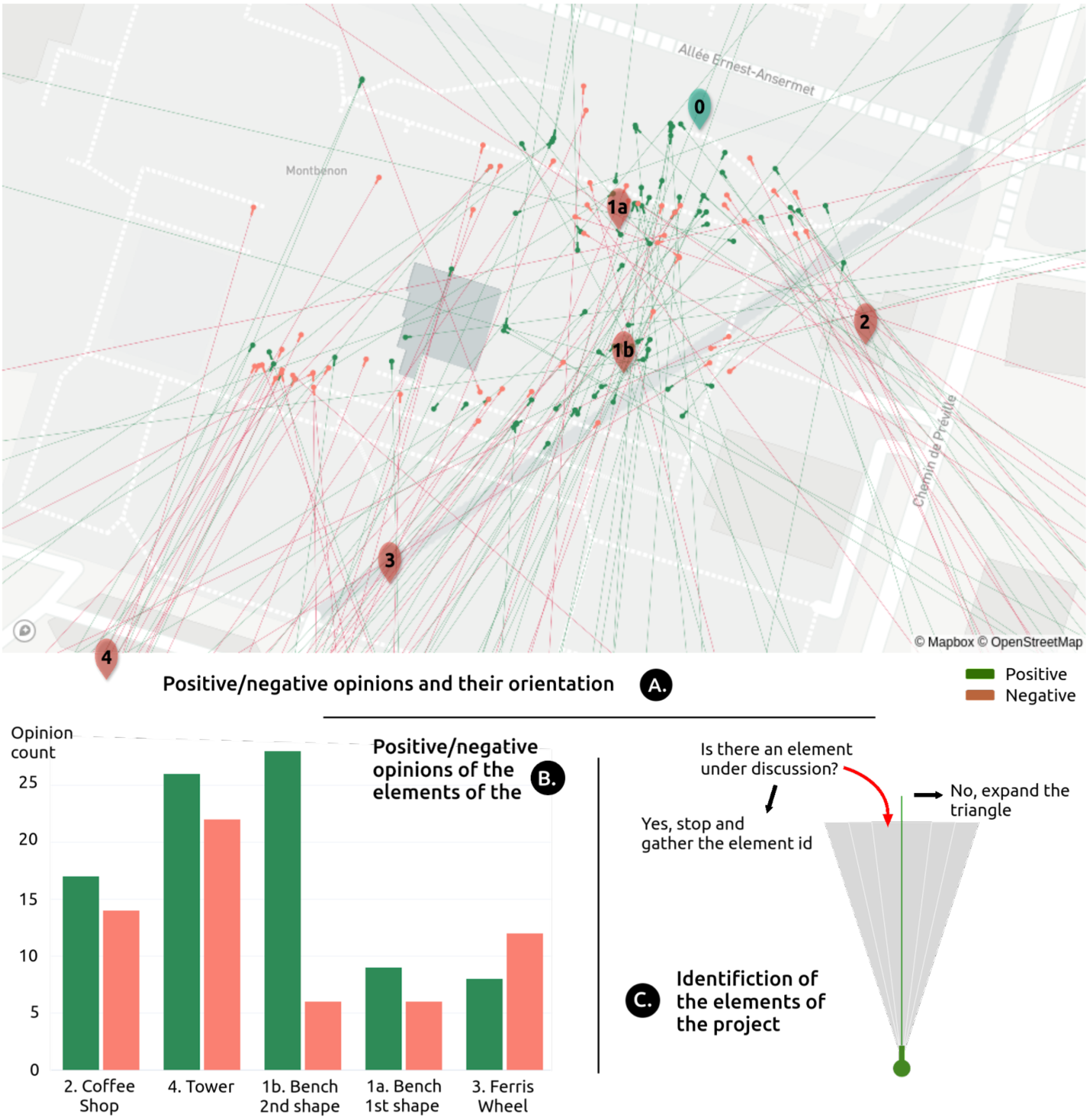

Figure 10.6. *Analysis of the project's elements targeted by the participant contributions. (1a) Raw orientations of the contributions are classified as positive/negative. (1b) Positive/negative distribution of the objects of the project. (1c) Adopted method to recover the targeted objects from a position and an orientation*

10.7.1.3. Additional Indicators

The data collected through the prototype and, therefore, the concept of e-guerilla participation could be further analyzed. In the previous section, we presented two indicators that are widely used by practitioners in urban participatory planning. In this section, we will mention other indicators that could be extracted from this collected data. First, it would be possible to continue the evaluation of the targeted objects (Figure 10.6) by applying a filter to the orientations and their identified objects. The resulting representation would display the position from which the project objects are tagged as positive or negative, thus, suggesting that certain points of view are considered more negative than positive. During the interviews, one participant mentions a positive opinion toward the Ferris wheel from a distant location, however, once at the base of the Ferris wheel, the opinion of the participant changed to negative (both of the points have been recorded).

Furthermore, the registered categories and tags can be assessed to identify the characteristics that are the most important for the participants. Table 10.2 introduces the count of tags recorded through the experiment without distinction between positive vs. negative. Table 10.2 shows tags that are clearly more employed by the participants, which indicates the significance of these characteristics. Assessing these tags through their positive vs. negative characteristics could also deliver additional information on which tags are the most significant for positive aspects, or on the contrary, which tags are the most important for negative aspects. This distribution can also be connected to the targeted objects to identify which qualities each of the objects have.

Tag	Count (N)
Height	29
Density	3
Aesthetic	45
Architecture	27
Price	8
Location	39
Noise	2
Atmosphere	36
Security	0
Sustainability	11
Conformity	12
Utility	35
Lack	6
Other	7

Table 10.2. *Assessment of the tags recorded by the participants*

Moreover, written and vocal comments can be valorized using machine learning, and more precisely Natural Language Processing (NLP). Vocal comments can be automatically transcribed and translated.

Good results were achieved with open source and free engines such as Librosa (McFee et al., 2022) and SpeechRecognition (Zhang, 2017) for the vocal to text transcription. On the text transcriptions, additional analysis can be performed such as a token classification (which can identify specific components of a sentence: adjective, individual, localization, object, etc.) or sentiment analysis (that computes sentiment from a sentence: anger, joy, confusion, etc.). We suggest exploring Hugging Face (huggingface.co) to obtain these NLP engines. Furthermore, through machine learning, the voice of the participants can be analyzed in the vocal comment. The voice conveys information about the sex and the approximate age of the person; these parameters could help to identify socio-demographic characteristics, which are not collected otherwise.

10.7.2. Participants' Feedback

The main goal of this study is to assess the usability of the guerilla e-participation concept, its applicability, and the experience of the users in using the prototype. The last survey and interview steps contribute to evaluating this goal. Figure 10.7 presents the key questions inquired during the survey. The answers were collected on a linker scale (1-5) from strongly agree to strongly disagree. The experience of the participants was collected in four main categories: feedback after using the app (A.), immersive feeling (B.), understanding of the project (C.), and the fit to urban participatory planning practices (D.).

Feedback on the App. Participants responded very positively to the use of the prototype (namely app in the questions). The prototype has been ranked as easy, quick, and fun to use by nearly all the participants. This feedback is crucial because these qualities are the core of the concept implemented in this study. The reduction of available functionalities within the prototype to comply with the simplicity described in the guerilla e-participation concept does not appear to be frustrating for the participants, who did not feel constrained for describing their contributions. The opportunity to skip or add information at any step seems to fit the expectation of the participants that they can contribute as much as they intend to. Moreover, the exploratory learning time was considered mostly positive with more than 80% of the participants indicating seamless handling of the prototype.

Immersivity. The questions about immersivity were also positively received by the participants of the study. The findings demonstrate a strong connection between the virtual and real environment, with a clear self-assessed feeling of immersion in the future layout of the place. Furthermore, not recalling issues with orientation implies a good fit of the orientation of the virtual scene with the real environment. Some offsets have been recorded by observation during the use of the prototype, however, in most cases, the offset was not noticed by the participants, who were too captivated by the virtual scene. The strong engagement with the prototype is demonstrated by more than 25% of the participants not being attentive to the surroundings. Following the observation notes, this number of 25% seems underestimated, because during the experiment some participants needed to be warned of the presence of people in the study area, one participant even mentioned the desire to step over one of the virtual benches, and a couple of participants even forgot to participate because there were absorbed by the prototype. Moreover, the lack of realism of the VGE has been communicated several times during the interviews, and in the survey around 70% of the participants would have preferred more realism. However, the abstraction of the virtual scene was not mentioned during the use of the prototype, and it did not hinder its handling. The preference for more realism has only been stated after the experiment, during the survey, or during the interviews.

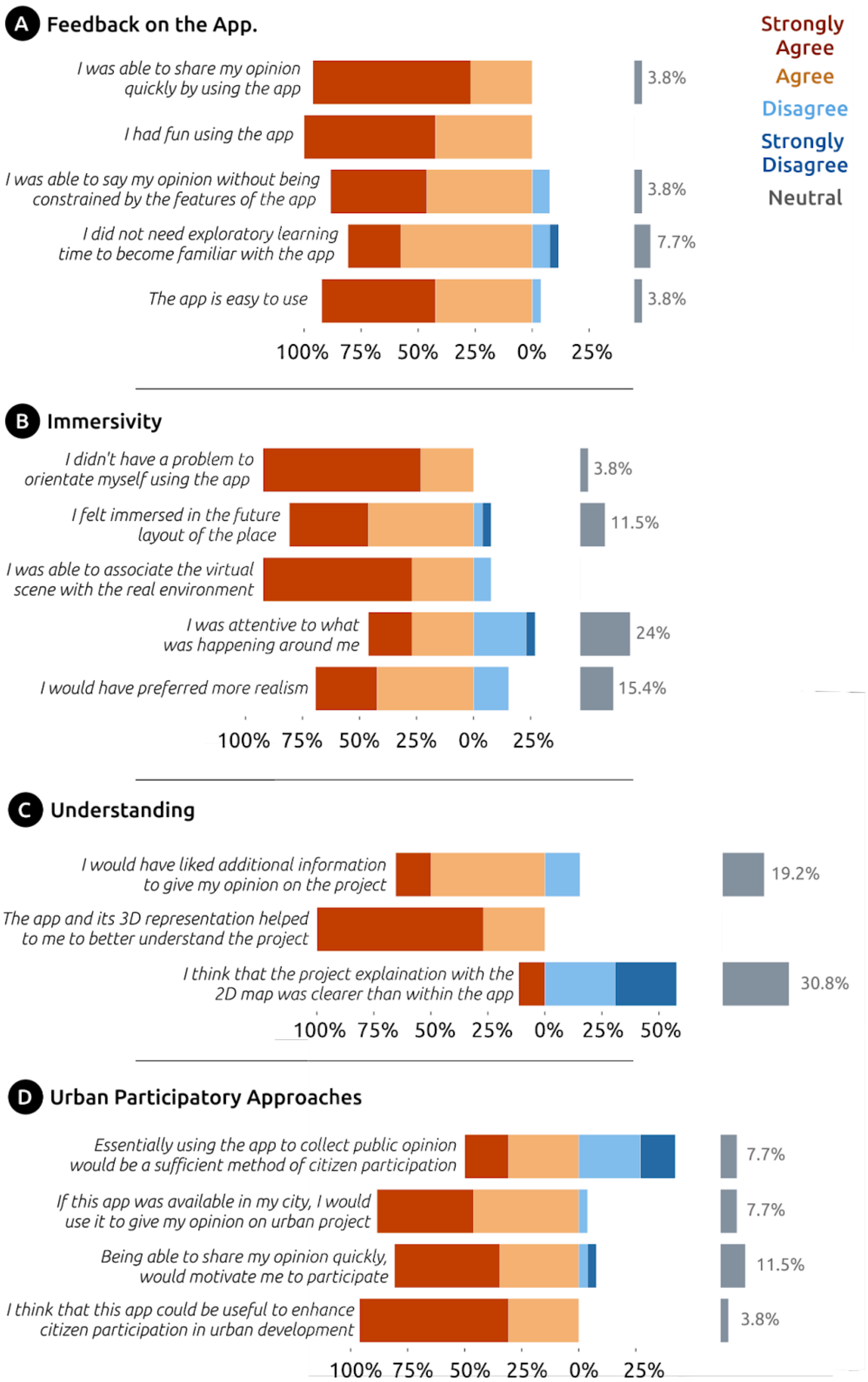

Figure 10.7. *Results of the survey, portrayed on a Likert scale*

Understanding. Before engaging with the prototype, the future project was presented in situ with the help of a 2D map and oral explanations. The questions related to the understanding are the assessment of the role of 3D to improve the comprehension of a future project. Surprisingly, all 26 participants recorded a positive impact of 3D and the prototype to facilitate the understanding of the project with around 75% strongly agreeing with the statement. Opposingly, most of the participants felt neutral (30%) or negative (>50%) with the fact their understanding of the project was clearer with the 2D explanation. This last statement is undoubtedly affected by the spoken qualities of a facilitator, but an outstanding presentation of the project with the 2D map is insufficient to reverse the tide. However, using the prototype the participants expressed the need for more information, which could hypothetically be implemented directly within the prototype with links to additional documentation.

Urban Participatory Approaches. According to the participants of the study, the prototype and the e-guerilla 3D participatory concept appear to enhance participatory approaches. Participants acknowledged the usefulness of the prototype for urban participatory development. Furthermore, they indicated that quick participation is a significant incentive to encourage their participation, recalling the fact that participants considered the prototype as a good channel to contribute quickly. We can postulate that the concept of guerilla e-participation could improve and increase public participation. Additionally, participants reported their desire to use the prototype if available in their city. However, the prototype as a unique means of engagement appears to be more dividing. Some participants indicated their disagreement with using only a prototype, but 50% would consider it sufficient. Therefore, participatory approaches should be customizable to fit urban dwellers' expectations, i.e., providing opportunities to deepen the engagement with other participatory mediums for the individuals who desire it.

A step of the survey (following the testing of the prototype) collected socio-demographic characteristics. Based on these characteristics and the answers to the question of the survey, we computed a correlation matrix between these two parameters. The results are depicted in Figure 10.8. The correlation matrix portrays 2-by-2 the correlation coefficient for these parameters. The blue color indicates a negative correlation and the red color portrays a positive correlation. Not all the pairs of parameters will be described.

This correlation matrix was computed to investigate how socio-demographic characteristics have possibly affected the answer to the survey. Seven characteristics were denied: gender, age, digital skills, 3D skills, urban planning knowledge, attended participatory session (if a participant has already been involved in a participatory session), and street use of a smartphone (if a participant tends to use their smartphone in the street). These characteristics have been encoded in increasing numerical values to compute the matrix. The findings show that age is negatively correlated with the fact that the prototype can be useful to enhance participatory planning and use the app as a unique participatory tool. Therefore, the higher age means fewer expectations with the e-guerilla participation concept. Regarding digital skills, an increase in proficiency appears to be correlated to easier handling of the prototype and the value expectation of quick engagement with digital tools only. However, higher familiarity with 3D technologies implies a higher requirement for realism and less immersivity. More expertise in urban planning, by an increased knowledge or involvement in participatory sessions, seems to be related to less enthusiasm in adopting the prototype in urban participatory planning. The opposite relationship can be observed for frequent users of smartphones.

These correlations are discussed for only 26 participants that mainly answered with similar points of view. Therefore, a few individuals can impact the observed differences, and these differences can be measured on answers that are positive (strongly agree vs. agree).

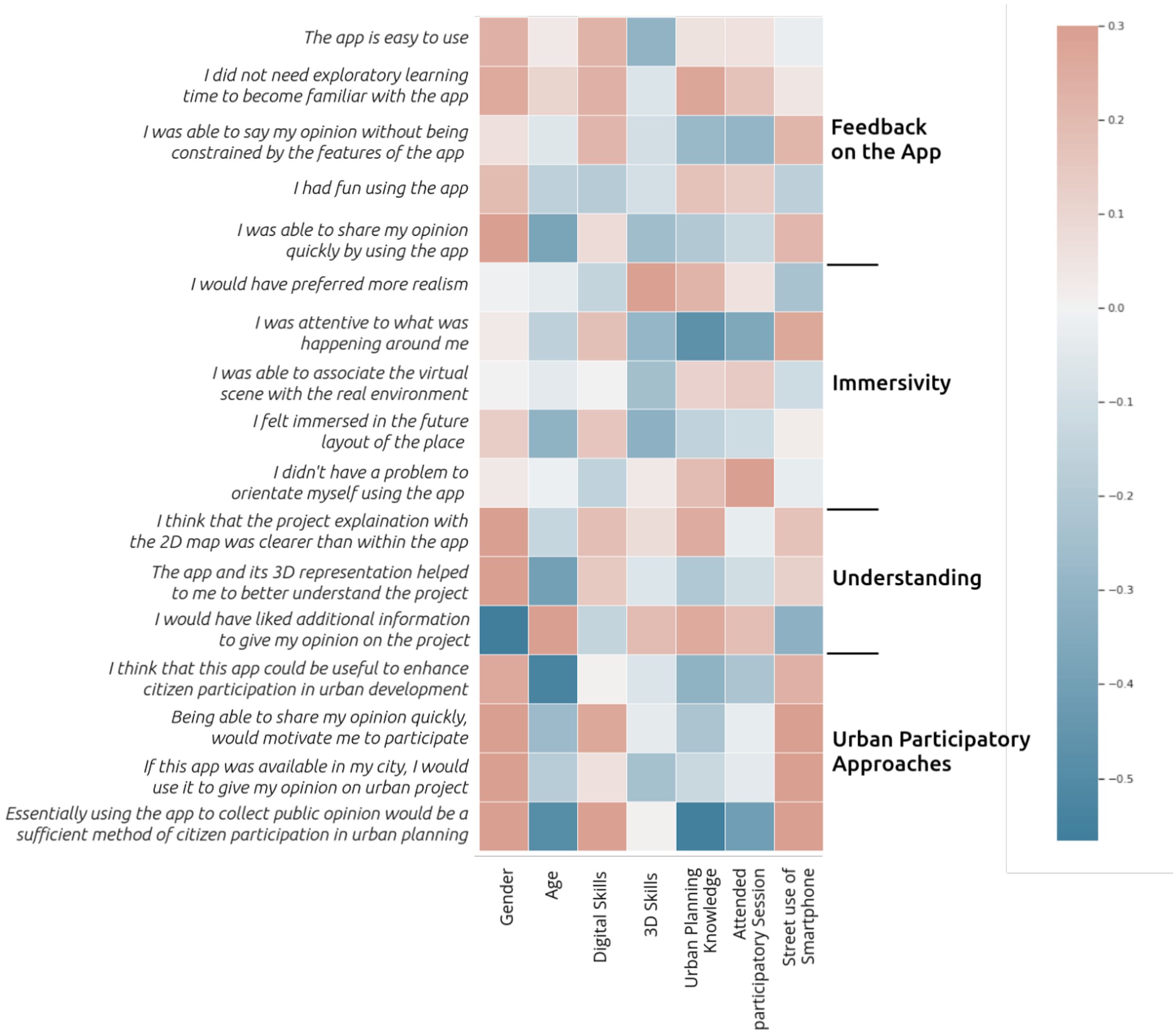

Figure 10.8*. Correlation matrix between socio-demographic characteristics of the participants and their answers in the survey*

10.8. Discussion

10.8.1. E-guerrilla Concept to Urban Participatory Planning

The concept of e-guerilla participation that has been detailed in this study demonstrated a strong potential for participatory planning. The results of the usability study portrayed informative output about participants' preferences on the project under discussion, with the highlight of the areas and objects of controversy. During the interviews, most of the participants mentioned the simplicity of the prototype (the interactions are more natural than a mouse/keyboard), its immersive qualities, and its originality, which are also observable in the answers to the survey. Being able to explore the project in situ has been acknowledged as an engaging way to participate, with an expert participant comparing the tool as an upgrade of a typical survey that could lower their dropping rate. Moreover, the immersivity facilitated the comprehension of the project. Some participants even compared the prototype to a video game. We also observed three participants that forgot to contribute because they were completely captivated by the VGE. Moreover, an expert participant mentioned that the virtual immersion in the project can adjust the participants' mental representation of the different elements, for instance, the Ferris wheel is often mentally pictured by its structure (a base and a circle), however, cabins and the spokes are often forgotten. Some challenges and issues were also raised during the interviews, and the engagement of the elderly was discussed. Seniors tend to experience hardship when interacting with cognitively expensive tools (Kessels et al., 2010; Lokka & Çöltekin, 2020), such as VGE. However, the prototype was designed to have natural interactive metaphors that lower the cognitive load, and no major difficulties regarding the orientation and the connection with the virtual environment were observed for the two (tech-savvy) participants over 60 years old.

The objective is to design a tool that is as inclusive as possible, but by definition, the adoption of a participatory medium excludes some individuals due to their motivations, preferences, or abilities (Chassin, Cherqui, et al., 2021). The approach of e-guerilla 3D participation needs to be completed by other participatory mediums and sessions, but this modern approach aims at engaging individuals that are currently hard to reach or identify (day workers, young, tech-savvy) without introducing barriers too difficult to break down for the usual suspect of typical participatory approaches.

One of the expert participants raised some concerns about the virtual representation of objects of the project in 3D. The virtual project provides the opportunity to visualize future objects in their exact scale. Therefore, the observation location strongly affects the experience of the project, which can be positive if seen from far and above or negative due to its magnitude from near and below. Furthermore, each additional virtual object should be exact in terms of representation and dimension; these two elements are also impacting the participants' feedback. A delicate situation can result from a strong opposition of the population, which arises from the use of the prototype that portrays a virtual building bigger than the real expected dimensions. The impact of the 3D visualization of a project is significant on its outcome, however, legal public opposition can only be supported by the official dimensions and sections of the project shared during the legal public inquiry. Therefore, the use of 3D visuals from the prototype does not have any legal value but still represents an important input for decision-making processes.

10.8.2. Improvements of the Prototype

10.8.2.1. Realism

The features of the prototype were also extensively discussed during the interviews. Participants emphasized the simplicity of the interaction with the virtual geographic environment and the quality of the representation. However, most of the participants (including experts) ask for more realism and even stressed its necessity. The debate for more realism or more abstraction in virtual environments has been conflictual for years (Appleton & Lovett, 2003; Hayek, 2011; Voinov et al., 2018), and a fit-all-situation solution has not been acknowledged in the scientific community. Regarding the prototype, the main topics were the vegetation and the basemap. The representation of the trees within the VGE was recovered as the default style from the Swisstopo data. Trees are modeled in basic colors, trunk in brown and crown in green, and their size varied according to their registered height (see Figure 3). However, they all have a unique generic shape, which is not dynamic according to their species, or the shape of their canopy (following a prune or the season). The expert participants stressed the importance of trees and greenery in every urban project since natural elements are crucial for the population (Chételat, 2005). Therefore, a recommendation would be to improve the realism of these green elements in the VGE. The second aspect of realism was the basemap. The selected abstract representation (also from Swisstopo) did not contain enough granularity and the virtual colors were different from the real elements, such as the pathways (see Figure 3). A solution often mentioned was to adopt a satellite image instead, however, the implementation of a photo-realistic component with the abstract representation of the trees and the buildings could potentially be too contrasting. Therefore, an adequate approach would be to use the main color of the real component to texture the virtual component within the virtual environment, which would improve the realism of the scene without demanding excessive time for the redesign of the elements or computational power to render the VGE. Due to the realism in the CGI (computer-generated imagery) and the video game industry, the expectation for realism can be considered as disproportionate compared to the time and budget provided to urban participatory approaches.

10.8.2.2. Participatory task

The tasks that participants had to perform were well understood and did not present any difficulties. However, participants indicated issues in identifying which elements are under negotiation. These elements implemented in the virtual environment were not contrasting enough to be understood as interactive. A radar showing the location of the objects has been implemented in the prototype but the radar was portrayed as unclear (regarding the distances) or was not consulted by the participants. An improvement could be to create an exclamation mark on the top of each object under discussion. The addition of this sign could create contrast within the virtual environment, hence encouraging participants to interact with the object. These mechanisms could also leverage another concern specified by the participants, which is the lack of information related to the objects. In the prototype, each of the objects was connected to a simplified information box, which appears when a project object was clicked. However, due to the lack of contrast of the virtual project objects, only half of the participants consulted this information box, which partially explains the lack of information. Furthermore, the oversimplified information box was too brief, participants (and experts) requested more information such as the material employed, the cost of the object, or a photo-montage depicting the object.

The step, where participants had to select the tags, was not well understood. Too many tags were present at this step, which forced the participant to take a significant amount of time to get familiar with them, which is not in line with the immediate participation dimension. Furthermore, the tags were not responsive to the participants' previous steps, which leads to disorientation. Some of the tags have been rarely or never used, therefore their usefulness can be questioned. The objective of these tags was to enable the participants to add supplementary information to their contribution and to provide categories in the data that could be analyzed. Six tags were extensively used, an improvement to this tagging mechanism would be to reduce the number of tags shown to the participants or to display them according to the participants' inputs.

10.8.2.3. Applied scenarios

The prototype has been tested to immerse the participants in a future project just before a legal public inquiry, which allows the population to legally oppose the project under discussion. In this scenario, participants were able to discuss objects of the project that they like or dislike through the prototype. This implementation is one specific example of the opportunity offered by the e-guerrilla 3D participation approach. One of the topics reviewed with the expert participants during the interviews was the potential applications of this approach in other contexts. Several propositions were discussed.

One scenario, similar to the one implemented, mentioned the adoption of the approach for revisiting the legal public inquiry. This process is not appealing to the population that only has 30 days to visit in-person the city office to consult the legal documents (which are not easy to understand). This legal step is often associated with a physical mock-up placed *in situ* at a 1:1 scale. However, these mock-ups are created by placing vertical poles in the landscape, which can be hard to apprehend for non-expert eyes. The approach demonstrated in this study could facilitate the visualization of the project's mock-up, and improve its legibility.

Another mentioned scenario is the comparison of different alternative projects. Using the prototype, the participants could be immersed in different projects, such as street furniture layouts, building materials, or architecture designs. The virtual exploration of these future alternatives could help the participants to better understand the impact of the project on the urban landscape. The prototype could also enable voting for the preferred alternative.

Furthermore, the prototype could also be adopted as a simple informative tool.

10.8.3. Limits

Some limitations of this study should be mentioned. First, the limited number of participants (<30) that were involved in the usability study, increases the weight of each participant's answers and disrupts the significance of the statistical tests. The study is also subjected to bias introduced by the presence of the facilitator (also called the presenter bias) (Dell et al., 2012). This bias suggests that participants tend to give more positive feedback to the technological solution that has been implemented by the presenter. This bias could have been significant due to the small number of participants in the survey and interview step of the usability study.

Second, other limitations are related to the prototype. The libraries used to implement the prototype are still not completely stable and not all browsers are compatible (e.g., Safari and Firefox), which may lead to unexpected behavior on a larger scale. Moreover, the current versatility of smartphone offerings leads to confronting overwhelming differences in the consumer pockets in terms of screen sizes, browsers, or device architectures, which challenges the development of prototypes to be fully responsive. Also, the use of a virtual globe, to portray 3D objects, is computationally expensive, even with the recent technological optimization with WebGPU and 3D tiling, older devices may not be able to render the 3D environment.

Third, regarding the approach and the participatory task, quick digital interactions as implemented in our approach may alter the meaning of the participant's contributions and a gap could be introduced between the participants' original opinion and the one that is recorded within the prototype (especially when the opinion is nuanced). Last, as already mentioned earlier, a participatory medium will exclude some part of the population, therefore, this approach should be completed by other participatory sessions.

10.9. Conclusions and Perspectives

In this study, we introduced a new approach that transforms urban participatory e-planning with 3D technologies. The recent bandwidth development with 4G and 5G, in addition to the broad availability of public wi-fi hotspots, offers opportunities to reconnect the location of the population engagement with the area under transformation by the project. Therefore, based on this prospect our approach provides an *in situ* involvement of the participants, who can explore freely a future project in a semi-immersive environment using only their smartphones present in their pockets. A prototype was implemented and tested during a usability study. Expert and non-expert participants acknowledged the approach and the prototype as refreshing and forward-looking.

We will now focus on improving the prototype by considering the aspects discussed with the participants and strengthening the quality of the output of the prototype by adding new analyses. One key missing component is a real-time administrative visualization tool. This component (e.g., a dashboard) could be valuable to practitioners, who would be able to easily assess the status of the participatory session. The ultimate goal of these improvements would be to design a prototype mature enough to discuss with municipality officials about its applicability in a real case project. Testing the prototype in this context would allow us to evaluate the range of the participatory transformations promoted by our approach.

The mentioned flexibility in our approach aspires to create a participatory medium that could be suitable for a large range of contexts (i.e., generic), which are inherent to urban participatory planning. The use of 3D visualizations requires specific data, which is most of the time not available (hence time-consuming to create), or pricey. The difficult access to this data can hinder the adoption of 3D visualizations in participatory planning approaches, however, this data is becoming gradually available with open data initiatives, Volunteered Geographic Information (VGI) projects (e.g., OpenStreetMap Buildings, osmbuildings.org), or LIDAR data (necessary for self-driving car). Generic participatory tools could facilitate the implementation of 3D technologies in participatory planning projects in terms of creation time and qualifications (coding, knowledge, etc.), hence providing more opportunities to the authorities (that not always have the capacities) to adopt advanced participatory mechanisms, which could ultimately lead to more meaningful and inclusive participatory planning.

Acknowledgments

We would like to thank the participants for their generous time and valuable feedback that made this project possible. The in-house code used in this study is under the MIT license available on GitHub: https://github.com/thibaud-c/VirtualCesiumPortal

Chapter

11. General Discussions

List of abbreviations for the chapter:

ICT: Information Communication Technologies
VGE: Virtual Geographic Environment
G2C: Government to Citizens
GIS: Geographic Information Systems
ICA: International Cartographic Association
OGC: Open Geospatial Consortium

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The previously stated gap highlights the lack of knowledge of the institution facing digital urban participatory practices, which leads to inhibit the opportunities provided by ICT-enabled and 3D-enabled tools. In this research, I investigated the limited applications that adopt digital 3D visualizations in urban participatory planning in order to dissect the complexity and challenges introduced by the practices of these modern participatory tools. Three focuses were consecutively considered: the practices, the participants, and the medium. Furthermore, I explore future prospects for Civic Technologies and participatory approaches in using 3D-enabled mediums through the promotion of a set of guidelines, which was mobilized in introducing a modern participatory approach. From the perspective of the population, this new approach aims at reducing the cost and the burden of participation. Moreover, this research was articulated around research questions, which will be addressed one by one in this section.

11.1. Addressing the Research Goals

The findings of my Ph.D. research are developed around challenges that encompass the adoption of digital 3D in urban participatory planning. Six articles were submitted or published, and each one of them proposes a different lens to understand better the meaning of the adoption of 3D in participatory practices. These lenses are:

- the perception of 3D in participatory planning by practitioners and the Media
- the challenges of designing this type of tool to be efficient and relevant
- the issues of reaching a targeted public

- the perception of the virtual geographic environment (i.e., 3D) by participants
- the behaviors of the participants that are induced by the adoption of 3D
- the suggestion of a modern approach to reconciling the space where the participatory session takes place with the place under transformation

These articles develop concepts, considerations, and results to address the research goals introduced in chapter 1.

11.1.1. Current Practices

***RG1.1**. Can typical practices be identified in urban participatory planning that adopts 3D visualizations? How 3D visualizations are applied in these approaches?*

In chapter 5, the described 132 media articles, which were published worldwide between January 2015 and December 2021 contribute to outlining a critical discussion on current participatory practices. These articles portray media stories about the adoption of digitally generated 3D visuals in applied urban participatory projects. Two key aspects were evaluated to describe typical 3D participatory planning practices, namely contextual factors, and technical parameters.

The findings showed that in most cases, 3D visualizations are adopted in medium scale projects, during the end of the design phase, with settings that tend to passively engage the participants, who only have scarce control over the visuals. These factors highlight practices that intend to inform or even convince the urban dwellers of the benefits of the project, i.e., one-way communication flow (Rowe & Frewer, 2000). This result is emphasized by the sharp details and high realism of the 3D visuals (which vary according to the scale of the project). Therefore, the collected media articles demonstrate only rare examples of true involvement of the population. These specific examples appear to be conducted through 3D tools that are not originally developed for this purpose (such as Digital Twins and video games).

Furthermore, only 132 media articles were collected, which appear small in quantity for a large-scale coverage that was concerning French and English-language media. Despite a heterogeneous terminology, which challenges the gathering of articles, this lack of mentions of 3D participatory planning in the media seems to indicate a poor enthusiasm around the 3D participatory practices. This skepticism in endorsing 3D tools was also observed during the exchange conducted with the different municipalities about the adoption of the 3D prototypes developed during this Ph.D. research, see chapter 4. However, examples from the scientific literature demonstrate numerous qualities of 3D and ICT-based tools (Bugs et al., 2010; Jacquinod & Bonaccorsi, 2019; Onitsuka et al., 2018). These two opposite outlooks highlight a gap between the scientific acknowledgment and advancement, and the practical endorsement by practitioners and institutions, also defined as the implementation gap. This gap has been largely discussed with the adoption of Planning Support Systems (Geertman, 2017; Jiang et al., 2020; Punt et al., 2020; Te Brommelstroet, 2010), which despite its acknowledged benefits, is scarcely used by practitioners and considered abstract and complex.

Two interviews, conducted during my research, may stimulate an original discussion on the implementation gap observed for 3D participatory e-planning tools. The first was conducted with the cadastral department of Geneva, which in addition to having one of the most detailed VGE of Switzerland representing the entire buildings of the Geneva canton, portrays in 3D the planned buildings in a pink abstract representation (Figure 11.1 on the left). The second interview concerned the GIS department of Neuchâtel, which developed an accurate photo-realistic representation of the construction of a new road broadcast as a video to communicate about the project (Figure 11.1 on the right). The common theme of these examples is that at first, the 3D visualization struggled to convince, and elected officials were either unaware or hesitant in the adoption of a technological choice. By endorsing these technologies, the authorities, elected officials, and, in general, the city takes a risk. If the adoption of the technologies is successful, the city taking the risk will be seen as positive by its population. However, in the opposite case, the authorities will have to face an uncomfortable situation, where the perception of the city by the population can be tarnished and the elected officials challenged in future elections. In both cases bridging the implementation, the gap was determined by one person's initiative and eagerness to adopt 3D tools. After the first positive feedback from the 3D tools, skepticism towards 3D was undercut, and the likelihood of adopting 3D tools in future projects was enhanced.

Figure 11.1. (left) *web application depicting built and planned (in pink) 3D buildings in Geneva*[40]*. (right) a video depicting the new road project in Neuchâtel*[41]

***RQ1.a**. Is the adoption of 3D visualizations in urban participatory planning evolving over time? Did the COVID-19 pandemic impact these practices?*

The COVID-19 pandemic affected the whole society. Urban participatory planning is still mostly operated through in-person approaches (even while using 3D tools). Therefore, with the sanitary restriction, which prevented any in-person gathering for months, participatory approaches were strongly affected. This drop can be observed in the number of media articles mentioning the use of 3D visual tools

[40] https://sitg.maps.arcgis.com/apps/webappviewer3d/index.html?id=091fef0b3c9346188f63a72e960bdf0d (retrieved the 18.07.2022)
[41] https://www.youtube.com/watch?v=XvpkAAN_-QQ (accessed the 18.07.2022)

in chapter 4. When compared to previous years, the number of articles is hindered in 2020.

From 2015 to 2021 (excluding 2020), the number of mentions (which remains low) does not depict any significant trend. This absence of inclination demonstrates that in 2021, the use of 3D visual tools did not rebound, despite the suitability of these tools for e-planning. One consideration provided from observations conducted on the shift to online participation during the COVID-19 pandemic is that most of the approaches that happened during this period only tried to mimic in-person sessions, which by nature cannot work. The adoption of technology, including 3D tools, in participatory planning, leads to a deep transformation of the practices, therefore, new methods should be mobilized to efficiently engage the population through technology. Adopting technology and 3D tools in participatory planning does not mean opening an unmanageable online video/chat room with participants and broadcasting a presentation or a video of the project and awaiting debate to start. Adopting technology is transforming the strategies to advertise the participatory approach, create incentives to participate, interact with the population, and provide feedback. This observation does not aim to blame practitioners for the unfortunate development of online participatory settings during the COVID-19 pandemic, numerous challenges had to be tackled before addressing a redesign of participatory approaches, such as the short time frame to conduct participatory processes, the lack of budget, or the conduction of these methods in the later phase of the urban projects.

***RG1.2**. What are the bottlenecks in adopting 3D visualizations in urban participatory practices?*

The challenges introduced in chapter 6 initiate a discussion about the several aspects that affect the design of 3D in urban participatory planning. These challenges contribute to bottlenecks in the broad adoption of 3D-based participatory tools in current practices. Three key factors were highlighted: the spatial scale, the project temporality, and the participants. The *spatial scale* was analyzed through the description of three types of urban projects (Arab, 2007): Architectural design, Major metropolitan, and Trans-urban. These types of projects that are linked together range from small to large scale and short to long temporality. Different scales have several impacts on participatory approaches. The spatial scale leads to different perceptions of the space (Montello, 1993), which impact the understanding of the participants and the way to represent the information. The temporal scale, which is often long, generates a distortion between the time of the engagement and the time of implementation of the outcomes of the participatory approach to the actual project. The time of dwellers' involvement happens months, even years before the same dwellers witness the impact of the urban project on their living environment. The *project temporality* was described through an evolution of the definition of the project over time that reduces the achievable changes over the same project (Midler, 1998). Any project, including urban, is following this pattern. Therefore, a 3D tool that is adopted in early projects will not have the same role as at a later phase. In the early phase, several changes can still be incorporated, which will gradually define the project. At this temporality, 3D tools can be used for design purposes with an abstract representation. In later phases, the project is completely defined (or close to being defined), which implies no evolution, hence, 3D tools will have an informative and communicative role. The last aspect affecting the design of 3D tools is the *participants*. Visualizations that are depicted in 3D are complex to perceive, this is due to the number of information that can be represented, and the necessary manipulation of the 3D scene to access all the information caused by occlusion. These two issues are linked to high cognitive load leads to fatigue and difficulties in using 3D visualizations. Strategies should be thus implemented to limit this cognitive load, guide the participant's attention, and assist them in their participatory tasks with neutrality.

The design of 3D tools is complex because as an interactive medium, it reflects the challenges in designing an adequate participatory planning approach, which is affected by numerous contextual elements. Chapter 6 highlights some challenges and suggests potential keys to addressing them such as a design pattern approach introduced by (Alexander et al., 1977), which aims at using pre-design components to manage pre-identified problems. Moreover, to be truly inclusive, additional issues about the participant idiosyncrasies should be also considered. Participatory approaches are conducted for the population, potential participants should, therefore, be at the core of any design. Focus on user-friendliness, access, ease of use, acknowledgment of contributions, and quick feedback should be addressed before any other concerns. Several strategies can be deployed to improve the participant experience in using 3D tools, considering the lack of direct interaction with facilitators or experts as one of the main challenges of remote participation, two approaches can be explored. The first is the development of asynchronous dialogue between the participants and the experts as mentioned by (Hu et al., 2015). The second is the implementation of a digital assistant, which executes the interaction with the participants, as suggested by (Christophe, 2008).

11.1.2. Participants

RG2.1. - What proxy can be applied to evaluate the success of a participatory tool in mobilizing the right targeted public?

Chapter 7 discusses questions about the representativeness and inclusivity of interactive sessions. Several studies have explored the dynamics of representativeness and the relationship between the participant, the targeted public, and the population (Barnes et al., 2003; Bryson, 2004; Rowe & Frewer, 2000) and how technologies reshape these relationships (Berg et al., 2020; Santini & Carvalho, 2019). The issues often raised are articulated around the identification of the targeted public and the stakeholders invited to the participatory session. The adoption of a (digital or non-digital) participatory medium leads to a selective mechanism, which will exclude some parts of the population. Engaging all the users of an area under transformation is organizationally unattainable, ineffective, and unnecessary, but the resulting invitation process does not often provide the same opportunities to all the population and omits non-resident users, thus excluding valuable alternative perceptions of the project’s area (Onitsuka et al., 2018).

Considering the urban participatory approaches as a government to citizens (G2C) service, these approaches can be compared to another G2C extensively discussed in the scientific literature: the health care system. An efficient health care system is often associated with its broad access by the population (Levesque et al., 2013; Penchansky & Thomas, 1981; Saurman, 2016). From their similarities, I introduced a framework to evaluate participatory approaches and the selection of an interactive medium in terms of access of the population to an interactive session. In light of two applied use cases, the framework demonstrates accurate outcomes in the consideration of the participants for the design of interactive sessions.

The success of a participatory approach can be partially regarded as representativeness and inclusivity of the interactive sessions that are implemented. The selected medium could be a considerable incentive to mobilize the targeted public effectively. However, a singular participatory medium is not the solution.

Adopting a plurality of mediums should be considered to provide more inclusivity and representativeness to the interactive sessions (Rowe & Frewer, 2000; Žlender et al., 2021).

RG2.2. - How is the adoption of an online or offline medium impacting a participatory session and its engaged participants?

In this research, I addressed the representativeness and inclusiveness challenges of participatory approaches through seven dimensions of access. These dimensions are affected by the selection and the design of an interactive medium that engages certain individuals more than others. The seven dimensions (accessibility, availability, adequacy, affordability, acceptability, awareness, and attractiveness), some of them primarily described in a patient/healthcare relationship (Levesque et al., 2013; Penchansky & Thomas, 1981; Saurman, 2016) are articulated around tangible aspects such as distance or finance, but also psychological aspects such as preferences, heritage or perception. Each dimension has been described through a framework that aims to assist any organizer of the participatory session to assess hindrances and mobilization dynamics of potential participants beforehand. The framework can be also used for *a posteriori* evaluation of a session. The seven access dimensions and the population heterogeneity involve diverse preferences for participatory medium. Therefore, according to the selected medium (online vs. offline), some individuals will be harder to reach than others.

An additional aspect should be discussed in this section, the use of digital tools, including 3D and Civic Techs, can be vividly criticized by practitioners and academics for excluding a large part of the population due to the digital divide or for giving unbalanced leverage to a technocentric population (Santini & Carvalho, 2019; van Dijk, 2017). As mentioned, a few lines earlier, yes, considering digital tools as a unique medium, if adopted without other media, can lead to the exclusion of some individuals and community groups or have less impact on the process. However, the typical approaches have the same selection issue, where usual suspects depicted as male, senior, financially secure, and white are already well-known from participatory sessions (McLain et al., 2017). Considering that the number of participants is limited in in-person sessions, the legitimacy of these typical sessions can also be questioned. Furthermore, socio-demographic factors affected by the digital divide often portray marginal groups, who by definition are excluded from social dynamics (this socio-demographic profile is also often raised by practitioners). Therefore, these groups can be regarded as unreachable by any participatory medium that aims at mobilizing a mainstream population. Involving marginalized populations is meaningful for participatory approaches because these groups, often extensive users of public places, have a different perception of the urban landscape. Last but not least, as mentioned in chapter 2, participatory approaches and the involvement of the population in planning or decision-making is a matter of concern for Western countries, developed and wealthy enough to focus on the well-being of the population. Taking into account Europe and North America, the internet penetration rate (i.e., access to digital tools) is **91.6%** (Statista Research Department, 2022). The distribution of Internet access in these regions is undoubtedly unbalanced, but considering the broad population, the adoption of digital technologies cannot exclude a *large* part of the population (only less than 8%).

11.1.3. Medium

RG3.1. - How do parameters and types of a 3D medium affect the experience of participants during an interactive session? What 3D settings could enhance urban participatory e-planning approaches?

Chapters 8 and 9 discussed these two questions. The technical parameters of the 3D mediums affect how participants/users experience a VGE. Some parameters such as the nature of the task can complexify the interaction, hence, limiting the access to the participatory session using the 3D medium. Three gaps were investigated: creator/viewer, viewer/viewer, and the adopted format to broadcast the 3D tool. The performance of the participants (in terms of the number of inputs, time to complete a task, and correctness score) was evaluated for different levels of realism, representations, and tasks. The findings demonstrated an impact of the representation/detail on the time to complete certain tasks, where a low Level of Detail and the presence of visual elements to attract the attention of the participant seem to be more efficient. However, an increase in realism does not seem to be hindering, despite the increase in visual information and thus in cognitive load. The VGE that were designed in the experiment lack contextual elements (such as urban furniture, or vegetation) that could have increasingly cluttered the scene, and therefore impact the results. However, the format appears to have a recurrent significant impact on participant performance regarding the correctness and time for completion. Three formats have been designed, an interactive 3D, and two formats that mimicked typical practices of 3D visual tools in participatory sessions, namely the individual broadcast of a video and static visuals on a picture. Therefore, more typical 3D participatory settings manifest significant inefficiency compared to a fully interactive VGE. Hence, the transformation of current practices is needed to promote the full potential of 3D participatory mediums.

The influence of socio-demographic characteristics on participant performance has also been explored. Age appears to play a role in the number of inputs and the time completion, which are both increasing with age. The sex of the participant (probably linked to other factors) affects the correctness scores. Moreover, one characteristic that has been demonstrated as critical is the spatial abilities that concerned nearly 20% of participants in the study. Therefore, one in five individuals performed poorly in each of the recorded dimensions when interacting with VGE. Considering that the controls implemented in the study were reduced to their minimum, the adoption of more advanced interaction could quickly be hindering to reaching an inclusive form of participation. Based on these findings I suggest the implementation of digital assistants (Christophe, 2008) that could react according to participants' behavior, ease or difficulties. However, a simple digital assistant is not sufficient to completely address this challenge, and innovative methods of 3D engagement should be explored, which is the issue investigated in chapter 10.

RG3.2. - Do the participants develop specific behaviors or strategies while interacting with a 3D medium? If so, which ones?

Chapter 9 investigated the participants' behavior induced by the interaction with VGE in participatory tasks. The findings highlight that participants are developing behavioral strategies that are improved over time. A learning curve was indeed observed for the number of inputs over time, which implies that participants are using less input to complete a task from the second encounter with a task. Therefore, participants are quickly learning to be more efficient with their tasks over time. Also, the overall strategy for completing a task has been identified. This strategy is divided into three components: a first exploration phase, a traveling phase to the solution, and an answer estimation phase. The first and the last phase have been shown to be very important to the participants to anchor their perception and then confirm their understanding following the execution of the tasks. Additionally, an indicator has been introduced to assess the difficulty of interaction with 3D in real-time.

These findings are crucial for the design of enhanced 3D tools for urban participatory e-planning. An accurate understanding of the interactive strategies and the behaviors of participants could help to leverage challenges in their manipulation. Strategies and behavior that shows hardship in using a 3D tool could therefore be identified, and digital aid provided to the concerned participants. A. Çöltekin et al. observed three challenges in the design of geo-visualizations: data & technology, representation, and human factors (Çöltekin et al., 2017). Interactive sessions should focus on the last aspect, the human factors. Various participants are engaged during an interactive session, and each of these individuals has preferences and specific skills, which can be echoed in the data & technology, and representations. Considering a 3D visualization that is static in terms of data & technology, and representation; the pre-select set of parameters that compose the 3D visualization may not fit all the individuals (skills or preferences). However, 3D visualizations that can be flexible according to the individuals, i.e., customizable, would ultimately lead to mobilizing more participants. The findings demonstrated in chapter 9, offer alternatives to reach this level of flexibility, and to fit the design of a 3D visualization to an increasing number of individuals.

11.1.4. Future Practices

RG4.1. - Which 3D settings in participatory e-planning projects could improve the mobilization of the participants and comply with the democratic values (inclusiveness and representativeness) promoted by those approaches?

The last interest of this Ph.D. research is the future of 3D urban participatory e-practices. By using the term "future," I consider approaches that can be currently implemented using the full potential of VGE; approaches that could appear Sci-Fi in today's context, but that are possible with devices currently in the market and in everyone's pocket: smartphones. In chapter 10, I introduce the approach of 3D e-guerrilla participation, which aspires to improve current practices. The approach is based on five dimensions: immediate participation, easy-to-use, flexible, place-based, and immersive. The idea of immediate participation aims at providing more freedom to the participants to choose the modality of engagement that suits them, notably by designing a tool that allows involvement on the go for only a few minutes. The easy-to-use dimension is related to a tool that is straightforward to understand, and that includes a participatory toolbox of the right amount of functionality - no more, no less. The flexible concept aspires to create a participatory tool that can be adapted to the different contexts of participatory approaches and urban projects, but also to the participants' preferences and needs (for instance, have the opportunity to complement a contribution with additional information). The idea of place-based is to engage the participants *in situ*, in the area under transformation, as described by (Korn, 2013). Last, immersive means to involve the participants with 3D visualizations that are unambiguous, which are directly overlaying the area under transformation. The two last dimensions could help to increase engagement but also stimulate the collection of more meaningful and emotional contributions.

The future of 3D urban participatory e-planning practices should focus on designing interactive sessions that have the primary objective to fit the urban dwellers and not only the legal requirement of public participation that is enforced by the institutionalization of these practices. Fitting the population involves designing participatory tools that could stimulate the engagement of the “silent majority” (and the individuals already involved in participatory approaches) by introducing significant incentives such as limiting the time of engagement, providing quick feedback, or administering truly meaningful participation. The usability study, which was conducted with the last prototype (prototype 6, chapter 4), demonstrated a significant potential for these types of approaches. Non-experts and experts provided excellent feedback, and more importantly, both groups bonded with the future project, despite the early stage of the implementation. As already mentioned, the adoption of a singular interactive medium cannot be considered inclusive, however, giving the opportunity to all users of a public space to participate with a tool that is simple and accessible from a smartphone could be the first step to encouraging more dwellers in participatory approaches. Digital tools produce contributions that could be considered less substantial than the output of in-person sessions, however, the objective of these e-tools is not to replace typical approaches, but to complete them. I suggest that digital participation should be conducted before in-person sessions; their outputs (based on a large sample of dwellers) can highlight areas or topics of controversy that need to be discussed further in an in-person setting.

11.2. Further Considerations

Civic Technologies (and GovTech) aspires to transform the interaction mechanisms between the institutions and the population. However, their use of ICT appears limited and often reduced to a web platform that only allows remote written discussions and polling. Creating a virtual interactive space, even text-based can improve the dialogue between stakeholders. Digital platforms are indeed more efficient regarding the number of people involved, the dynamic exchanges (synchronous or asynchronous), or the freedom provided to the participants (time and location) (Ertiö, 2015; Macintosh, 2004). In the context of urban participatory planning, the urban issue under discussion can be commonly complex, and written interaction alone can be unclear for some individuals. Therefore, new tools emerged to facilitate the interactions between the institution and the public on these (spatial) complex issues. PPGIS, participatory mapping, and VGI platforms are increasingly adopted within Civic Tech projects, such as Debatomap[42] to create geo-debate, Maptionaire[43] for geo-survey, or various reporting tools (e.g., fixmystreet[44],

[42] https://debatomap.reperageurbain.com/
[43] https://maptionnaire.com/
[44] https://www.fixmystreet.com/#

Signalez-nous[45]). Nevertheless, only rare projects are currently exploring the potential of the 3rd dimension to enhance the interaction between the institution and the population. In chapter 2, some of these projects (from an academic perspective) are described. Outside academia, the examples of 3D projects are uncommon, with only (to the best of my knowledge) OpenCities Planner[46], which is increasingly targeting experts. Therefore, with this Ph.D. research, I aspired to bring a new perspective on the understanding of the use of 3D visualizations in urban participatory planning and to promote their adoption to advance the transformation of the interaction between dwellers and institutions initiated by Civic Tech.

The technical plurality introduced by Civic Tech (Schrock, 2019) led to a vast number of project initiatives (Civic Tech Field, 2019), which galvanized an equally vast "graveyard" of unsuccessful projects (Hamm et al., 2021; Sifry, 2019). Facing this multitude, the authorities can be overwhelmed in selecting an alternative that fits its needs accurately. To overcome this issue, two alternatives are possible. The first is to limit the number of new participatory tools and implement new platforms only if necessary, which could lead to a reduced number of proven effective participatory e-tools. The second is the need to continue the innovation in participatory planning and urbanism (Arab & Vivant, 2018; Honey-Rosés, 2019). N. Arab and E. Vivant stressed that the concept of (participatory) urbanism is defined as an activity that explores, creates, and implements a space expressed by its use, role, and experience. Technologies (including 3D visualizations) could be one of the vehicles for such activity. Current planning practices (in-person or online) are still imperfect; exploring new practices and new tools is the most efficient mechanism to build knowledge and create momentum in an improvement process. However, the need to reinvent and enhance current practices does not only mean adopting additional (digital) tools in participatory practices, but it also implies transforming the approaches in which citizen participation is involved.

In chapter 2, I emphasize the difficulty of measuring the success of participatory approaches, or the impact of digital technologies in the practices. Currently, a considerable gap exists in the number of applied participatory initiatives, with a large dominance of in-person settings. However, Civic Tech projects certainly create more space for the population to be involved in governance, hence promoting a larger pool of participants. In-person participatory settings can be discouraging for novice participants with their codes, complex interactions, vocal individuals, etc. Digital participation could hypothetically help novice participants assimilate the specific code and culture of in-person meetings, hence, legitimizing their subsequent participation in more traditional settings. Digital participation could therefore be perceived as a vehicle of socialization (Figure 11.2). Common participatory sessions are indeed still reserved for an exclusive part of the population, that already knows the participation codes and values, that is at ease to defend their position in front of a public, that knows the custom of participatory sessions, etc. Popularizing digital platforms supports the broader assimilation of these codes and values by online participants. These online shareholders (most of them are novices in participatory approaches) may develop an interest, a better understanding, and legitimacy to speak up in future participatory sessions.

[45] https://mapnv.ch/getitfixed/issues
[46] https://www.bentley.com/en/products/brands/opencities-planner

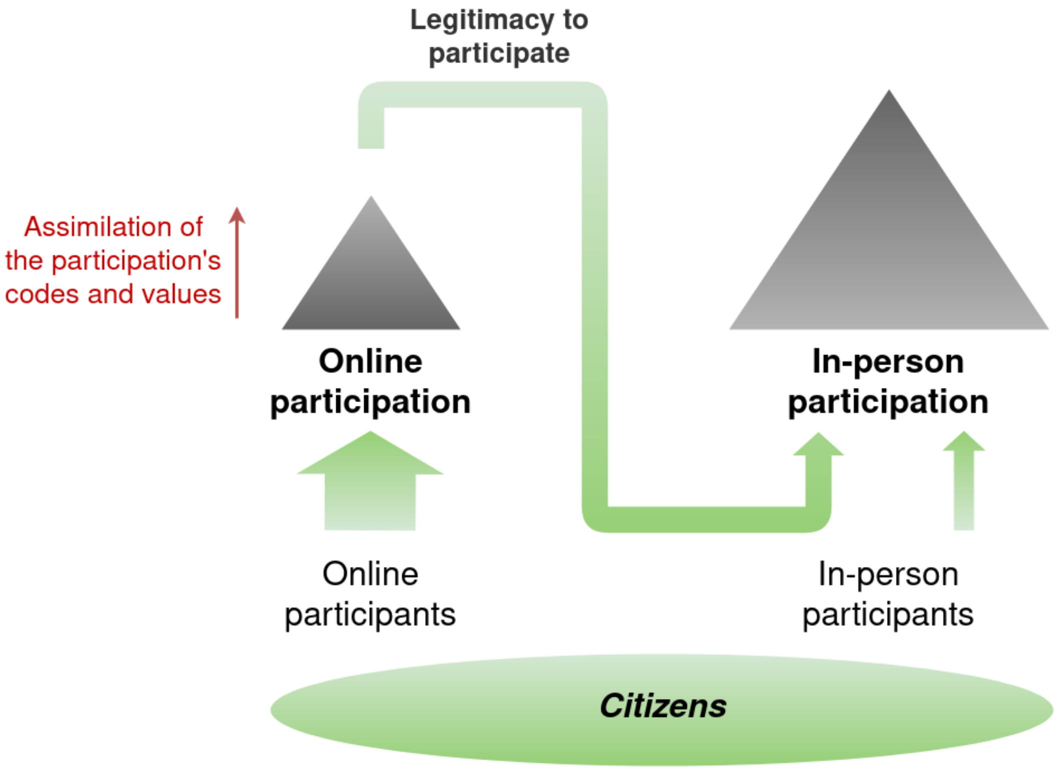

Figure 11.2. *Online participation as a vehicle of socialization*

11.3. Limits

Limitations of this research have been directly discussed in each chapter. However, some overall limitations should be mentioned. This research is transdisciplinary, therefore it is not conceivable that all aspects of urban participatory planning and 3D visualizations have been completely addressed. As demonstrated in this Ph.D. thesis, these two topics of interest are highly complex and dependent on several external parameters. Therefore, this research presents only highly specific focuses that are applicable for only a certain set up of parameters. Moreover, due to the specificity of a Ph.D. thesis, several elements could not be addressed.

My research partially mentioned the output of participatory planning. This issue is complex to address, which leads to only rare studies investigating the topic. By output, I mean the process that evaluates the data collected from the interactive session and its medium, to create tangible information that could be used in decision-making.

- My research is limited to the use of a virtual globe. However, several other 3D mediums could also be suitable to enhance participatory processes, such as video games or city models. Furthermore, the application of the third dimension is limited to a 2D screen; AR and immersive VR have not been considered. I selected a virtual globe to develop my research because this technology is highly flexible, scalable, browser-oriented, and already available. These elements provide a short-term application of my results for academics and practitioners. However, with the fast technologic evolution, new efficient mediums will be soon appropriate and implementable to complete the existing participatory tool pool and enhance urban participatory e-planning.

- The virtual scene portrayed within the prototypes was limited in terms of details and 3D objects. This impoverished visualization could have affected participants' behavior, performance, or perception. The addition of stimuli clutters the virtual environment (i.e., increased cognitive load); however, it can also make the virtual world more livable and, therefore, more engaging for the participants. One of the current major gaps in the application of 3D is the lack of exploitable and up-to-date data. Nevertheless, the current trend of open data promotes newly available data that is freely exploitable. This new information can contribute to designing engaging environments, where participants could relate more easily to the portrayed issues.

- The public of participatory processes is versatile. When I mentioned the population in this research, I did not consider the full range of the population, e.g., some of the marginal groups or the youth.

- The two user studies were conducted on a limited number of participants, which demonstrates credible findings. However, these studies should be reproduced in order to positively validate the results.

- The quantitative media coverage approach adopted in paper A could be more time efficient, and machine learning algorithms (i.e., Natural Language Processing) are a suitable tool to improve the method by automating the process of the media articles by tokenization and sentiment analysis.

The last element that I would like to mention is the gap between the development of prototypes in an academic outlook and the quality requirements of a tool that is production ready. The authorities struggle to endorse a prototype that is still in its early version, which is acceptable because the public image of the city is put at stake. However, the gap between an operational tool and an academic prototype is colossal with security standards, confidentiality agreements, no bug solutions, etc. The time required to fill this gap is extensive, and not a priority in research, which may be one reason for the implementation gap observed between the academic concepts and their implementation in the industry or real case scenarios. However, it is still unclear how to fill this implementation gap.

Should academics keep developing proof of concepts that are later taken over by the industry, or should academics learn additional technical skills to operate and finalize their solution? A brief answer is hard to outline. However, through this research, I intended to bridge this gap, and suggest that these two conceptions of innovation should foster collaborations. Projects operated by a partnership between the Academia and the Industry could benefit from complementary skills, which would ultimately result in more efficient participatory tools that are applicable, and more related to issues encountered by the practitioners. However, this collaboration should be preceded by the creation of a common vocabulary and knowledge base. An inspiring example can be recalled from the cartographic domain, where the International Cartographic Association (ICA) recently offered to connect more actively with the Open Geospatial Consortium (OGC) (Griffin et al., 2021). The OGC is an international consortium that aims at promoting open standards and is, therefore, focused on a more applied, mapmaking, software-oriented approach. This increased involvement of the ICA could improve the development of standards and tools to make the design of web maps following good cartographic practices more accessible.

Chapter

12. Conclusions and Perspectives

List of abbreviations for the chapter:

VGE: Virtual Geographic Environment
AR: Augmented Reality
VR: Virtual Reality
PPGIS: Public Participation Geographical Information Systems
VGI: Volunteered Geographic Information
BIM: Building Information Modeling
GIS: Geographical Information Systems
ML: Machine Learning
NLP: Natural Language Processing

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This last chapter aspires to outline various contributions of this Ph.D. research. As investigated through all the previous chapters, my research objective was to explore the adoption of 3D visualizations (embodied by Virtual Geographic Environments) in urban participatory e-planning. The adoption of such mediums transforms current practices by engaging the population in virtual interactive sessions through new mechanisms enhanced by the addition of the third dimension. However, the endorsement of these mediums (or any medium) in participatory approaches never results from a neutral decision made by the authorities. Each medium echoes differently with the preferences or abilities of the population which leads to mobilizing certain participants more than others. This Ph.D. research investigates, therefore the adoption of 3D visualizations in participatory practices as a whole, from the reshaping of the interaction between the participants and the medium to the enhancement of the current practices or the dynamics of selection following the adoption of a medium.

12.1. Contributions

This Ph.D. research, due to its transdisciplinary nature, contributes to several domains such as participatory sciences, urban planning, PPGIS, and 3D visualizations. The first focus on current practices highlights the limits and challenges of using digital 3D mediums in urban participatory planning. New notions have been introduced to describe and conceptualize the complexity of designing 3D participatory tools. Moreover, several applied implementations of digitally generated 3D visual tools have been dissected to spotlight the limited reach of the current practices. From potential hindrances, I suggested some mechanisms to leverage current bottlenecks, such as the concept of customization, which would allow the 3D medium to fit the urban context as well as the targeted audience. The second focus is articulated around the participants introducing a tool to support practitioners in the selection of an interactive medium. This tool is characterized by a framework that mobilizes the notion of access (first described from a healthcare perspective) in order to direct the selection process of an interactive medium on concerns related to the participants and the inclusivity of the participatory approaches. The introduced framework based on seven dimensions of access completes the current design mechanisms of participatory approaches by broadening their consideration. This framework can be use by practitioners who want to select (and evaluate) an interactive medium in accordance with the targeted public of a participatory approach. Furthermore, this second focus regards interactive mediums as a mobilization instrument, which reaches only a reduced part of the population and should be therefore combined with other participatory mediums in order to enhance the inclusivity and representativeness of the participatory practices. The third focus considers the 3D mediums and their conveyed experience. An accurate report of the participant's behaviors and performances has been established. Based on this new data, a set of recommendations have been suggested to enhance the design of 3D participatory tools. The advised elements aim at reducing the cognitive load introduced by the use of 3D visualizations and improving the performance of the participants, which could ultimately lead to less fatigue and more motivation in adopting these modern participatory tools. The last focus is articulated around the future of urban participatory practices and defines a modern participatory approach that enhances the in situ involvement of citizens through a 3D medium. The findings developed in the previous focus led to suggest this modern approach, which could leverage numerous challenges and increase the inclusivity of current participatory approaches.

This Ph.D. research offers numerous contributions to urban participatory e-planning. The findings of this research introduced a new transdisciplinary perspective, which emphasizes applied research. Therefore, these findings are immediately relevant to current practices. For instance, the prototypes that have been developed can be adopted in their present condition by the institutions to enhance next participatory practices. Furthermore, through my research, I aimed at addressing common challenges faced by the practitioners. This original approach led to addressing concerns about 3D geo-visualization and its design (in terms of portrayals and interactivity), but also to introducing mechanisms facilitating the design of the interactive sessions and the selection of their related medium. The exploration of VGE has been an extensive segment of this doctoral thesis, where the impact of different 3D settings has been evaluated. This segment related to the user study (chapters 8 and 9) emphasizes the urgent need to transform current practices in order to increasingly rely on interactive 3D geo-visualization, which would enhance the performances and the understanding of the participants. Equally critical for urban participatory planning, there is evidence to suggest that a significant segment of the population lacks acute spatial abilities, which is pivotal for any urban participatory approach adopting VGE or a more typical 2D map layout. Therefore, helping mechanisms should be implemented in order to thoughtfully mobilize this segment of the population, but also to value their contributions. Moreover, it is imperative to diversify the interactive mediums and to offer interactive sessions with other focus than map-based.

The findings developed in this research are also pertinent for the specific domains which encompass my research such as PPGIS, VGI, 3D cognition, participatory sciences, and urban planning. The focus on urban projects can be easily extended to landscape planning, policy-making and all the processes addressed by Civic Technologies.

The methods that have been designed to undertake this Ph.D. research are transferable for future academic investigations. First, the media coverage appears to be a complex but acceptable proxy to assess current challenges faced by practitioners, in addition to having an appropriate overview of the state-of-the-art of current applied practices (paper A). This applied perspective offers remarkable proximity to common practices, which seem to be more accurate than the academic point of view. Therefore, this type of method could help to reduce the implementation gap by reframing the scope of the academic research towards a more applied context. The analysis of media coverage, through a quantitative approach, should not aim at supplanting traditional approaches but could provide valuable supplementary findings and help academic research stay relevant from the perspective of practitioners. Second, the online study displayed in papers D and E illustrates the transformation of an advanced in-person user experiment into an online experiment. The steps that convert the experiment from a 180 minutes long on-site involvement to a 20 minutes long online study were described in the related papers. The online result involved several gamification elements in order to engage and motivate the participants to complete the survey, which was cognitively demanding. The addition of the gamification elements and the use of various communication channels helped to reach more than 200 different participants and to yield a completion rate of about 50%, which is positively unusual for this kind of study. Therefore, the method described in papers D and E and its success could stimulate the development of similar online studies. Third, the overall research approach adopted in this Ph.D. thesis is based on the implementation of iterative prototypes, which supported the investigation of hypotheses and research questions. These prototypes were then discussed with peers, and practitioners in order to evaluate their suitability for urban participatory practices. This method is inspired by Agile practices that are widely adopted in software development and has shown several benefits in my research. The short adaptive iterative loop promotes frequent feedback, which provides more opportunities for cooperating and refocusing my research questions and hypotheses according to the output of each iteration, thus making them more relevant for practitioners and academics. Therefore, the transdisciplinarity of my Ph.D. research has also been developed through the methodology, which has been proven valuable.

12.2. Perspectives on the prototypes and the experiences with the practitioners

The iterative development of the platforms promoted by this research allowed numerous observations, concept creations, and investigations. The exchanges with the municipality representatives were also productive, and even if the results were most of the time frustrating, the ability to observe the perspective of the authorities about participation was fruitful. The constant improvement and transformation of the prototypes resulted in the design of a new approach to enhance urban participatory planning through the use of digital 3D e-tools. Ease of use, quick participation, and inclusiveness seems to be the qualities of such tools. However, I met strong skepticism from the municipality officials, who do not seem willing to take the necessary risks in endorsing innovative 3D tools or modern approaches. The incentive of being perceived as a modern, digital city does not appear to be sufficient to convince the authorities to change their practices that are currently controlled, known, and comfortable.

Moreover, the lack of realism of the prototypes implemented in this Ph.D. research is unwelcomed by the authorities, notably because of the abstraction of the virtual environment contrasting with highly realistic 3D, which currently demands extensive time and substantial costs. This thirst for realism is also not in line with participatory projects that are often time-bound with a limited budget. However, enhanced realism today seems to be a mandatory step to perform in order to broaden the use of 3D e-tools in participatory planning. Therefore, from the inquiry raised nearly twenty years ago by Appleton and Lovett about the "sufficient realism" of a virtual environment in decision-making (Appleton & Lovett, 2003), an additional question can complete this prior inquiry today: What is the minimum acceptable (cost-effective) realism to make the institution adopt 3D participatory e-tools in planning?

Additionally, the perceived complexity of 3D e-tools and the hypothetic exclusion of parts of the population (especially older ones) was raised several times during the interaction with the authorities. The additional dimension to depict 3D adds a layer of complication and is often linked to a higher cognitive load than 2D representations. The manipulation of 3D objects is also not straightforward in front of a computer, however, the population is increasingly accustomed to 3D visualizations, passively through TV and movie theaters, but also actively via video games, virtual reality, and augmented reality. This increased familiarity with 3D objects does not overcome the need to design easy-to-use participatory e-tools, which could enhance the inclusivity of the practices. The last implemented prototype heads in this direction, with the creation of an interactive metaphor that is simply looking through the device in the intended direction. In addition, the absence of download time and installation requirements helps to engage participants right away with their task, i.e., reducing the waiting time or mandatory installation step that may distract the participants, and ultimately take them away from the participatory objectives. Also, designing affordances (i.e., perceivable actions) could help to enhance access to the tool and participatory session for a population that may be excluded by digital technologies, such as the elderly and digital outsiders.

Specifying the notion of inclusivity, most of the participatory approaches described in current practices emphasize participation that is situated in a remote location. A remote location can be defined as a location that is not situated *in situ*, i.e., distant from the area under transformation. Several organizational explanations (cost, management, material) can justify this choice, in addition to other requirements such as the consideration of the target public. This remote location raises two issues. First, the participatory location is only available at specific times, which reduces the opportunity to get involved for a large part of the population. Second, the communication channels employed by the authorities often invite local dwellers to the participatory session. The local citizens are indeed heavily affected by the urban project, but they are not the only users of the area under transformation; tourists or day workers are often forgotten. Digital participation is facing a similar issue. When regarding digital participation as a medium to increase the engagement of the population, notably in reaching the "silent majority", it means creating an inclusive approach. However, it seems that digital participation does not deliver all of its promised goals. Therefore, the last prototype that was implemented in this Ph.D. research aims at addressing these issues by designing a participatory approach that is advertised in situ, i.e., for all the users of a public space regarding their place of residence.

12.3. Summary of the Main Findings

The following elements regroup the crucial contributions of this Ph.D. research. These elements are deliberately not described in the form of recommendations. This Ph.D. research emphasizes from the beginning the versatility of urban participatory planning. Due to different contexts, participants, tools, or objectives the outline of hard guidelines to adopt 3D digital tools in participatory approaches is undoubtedly meant to be fruitless. Therefore, these next key elements should be regarded as facultative ingredients to design an interactive session and its medium, if chosen wisely in the appropriate quantity the resulting participatory approach could be enhanced and above all more inclusive.

❖ Current practices:

***Paper A:* Media Coverage of 3D Visual Tools Used in Urban Participatory Planning**

- ➔ 3D visualizations are mostly adopted for medium scale projects, during the (late) design phase, for the communication and promotion of the project
- ➔ 3D visualizations offer only limited interaction and are represented realistically with a very high LOD

- ➔ Involvement of the population (more complex interactions) are often supported by tools not primarily developed for urban participatory planning (such as video games or city models)
- ➔ 3D visualizations are mostly adopted in in-person sessions
- ➔ No established vocabulary describes the adoption of 3D visualizations in urban participatory planning

***Paper B:* Challenges in Creating a 3D Participatory Platform for Urban Development**

- ➔ Urban projects have different scales and temporalities, which does not allow to use a generic 3D visualization with a predefined set of functionalities
- ➔ Participants have different abilities; 3D visualization could be flexible to fit the participants' needs
- ➔ Efficient interactive sessions have two transformation mechanisms, the first is to translate the authorities' needs in adequate participatory tasks (that the participants will perform), the second is to transform the citizens' contributions in meaningful outputs
- ➔ Participatory approaches may adopt various medium (digital and non-digital) to improve their inclusivity

❖ Participants:

Paper C: Impact of Digital and Non-Digital Urban Participatory Approaches on Public Access Conditions

- ➔ Interactive sessions are subject to selection processes, which affect the representativeness of the participants attending the session
- ➔ The access evaluation of an interactive session that is adopting a specific medium is conducted through seven dimensions: accessibility, availability, adequacy, affordability, acceptability, awareness.
- ➔ These dimensions can be assessed before a session (to guide its design) or after a session (to evaluate the reasons for specific representativeness)
- ➔ The adoption of a 3D digital platform can simplify the interactive sessions by channeling the stakeholders' interactions within a unique virtual space

❖ 3D medium:

Paper D: Experiencing virtual geographic environment in urban 3D participatory e-planning: A user perspective

- ➔ Three gaps can lead to different understands: conceptual (creator/viewers), cognitive (viewers/viewers), and portrayal (broadcast format)
- ➔ The 3D representation (LOD and style) affects the participants' performances in terms of time to complete a participatory task. Decreasing LOD or the addition of a focus element increases the completion speed. However, photo-realistic representations appear not to decrease the performance of the participants
- ➔ The broadcast format (3D scene seen only once, or static images) are hindering the performance of the participants in terms of completion time and correctness
- ➔ Age and sex, and previous 3D consumption affects the performance. Older age is correlated with more time and inputs (lost efficiency). Sex impacts the correctness scores. And 3D consumption reduces the time needed to perform a task.
- ➔ Spatial abilities (nearly 20% of the participants) are crucial while experiencing VGE, a lack of these abilities leads to significant hardship
- ➔ Overall, participants felt more at ease with the introduction of an element helping to focus the participants’ attention. More visual cluttering, i.e., realistic texture, leads to more perceived difficulty

Paper E: Experiencing virtual geographic environment in urban 3D participatory e-planning: A user perspective

- ➔ Participants are developing specific behavior while manipulating VGE and become rapidly more efficient (fewer inputs are needed to complete a task)
- ➔ Real-time indicators can be easily computed, which could help to provide dynamic assistance to the participants according to their experiences
- ➔ Most of the participants develop the same strategy while performing a task: prior understanding phase (around the landing location), exploration phase, and final assessment phase (around the tasks location). The first and the last phase constitute most of the interaction. Locations can be highlighted within a VGE by wisely selecting the landing location and the task to perform

❖ Future practices:

Paper F: E-Guerrilla 3D Participation: Approach, Implementation, and Usability Study

- ➔ Five dimensions of 3D tools can enhance the participants' engagement: immediate participation (the participants can quickly contribute), easy-to-use, flexible, place-based (the participants a involve *in situ*), immersive
- ➔ 3D visualization helps to the comprehension of urban projects
- ➔ Quick engagement and communication about a participatory approach seem to be essential to increase the number of participants
- ➔ Simple participation needs to be completed by other methods
- ➔ Realism is a significant aspect of 3D participatory e-practices, the integration of realistic elements could primarily be focused on the vegetation
- ➔ In a 3D visualization element transformed by the urban project (added, deleted, or modified) could be highlighted within the virtual environment to enhance the comprehension

12.4. Future Work

Based on the research approach described in chapter 4, the future short-term direction of this work would be to continue applying the established methodology in participatory approaches. The last prototype presented in chapter 10 was tested and evaluated with participants. The results showed a significant potential for the implemented prototype, which has been acknowledged by experts and non-experts. Therefore, the adoption of 3D mediums in participatory planning could promote an enhanced involvement of the population, by creating more immersive and engaging interactive sessions. Room for improvement was also identified. Therefore, a new cycle could begin by identifying further hypotheses based on the findings described in chapter 10 and the participants' feedback. The resulting prototype, which would be more mature, could be discussed with authorities to assess the validity of the approach of e-guerrilla 3D participation. Finding a partner institution would be also relevant for future work, where new prototypes could be tested in real and adapted in case scenarios. This could improve the relevance of the results demonstrated in my Ph.D. research as well as contributing to build a first case study that could help to leverage following implementations.

Current and Future practices:

My Ph.D. research outlines the adoption of a 3D medium in top-down (initiated and managed by the institution) processes. One outlook that could be explored is the opposite approach, initiatives triggered by the citizens, i.e., bottom-up processes. Bottom-up participation interests are articulated around empowerment, inclusion, leverage, and cost-effectiveness (White, 1996). Furthermore, these processes stimulate social learning that builds a shared understanding through information and the discussion of different perspectives (Koontz, 2014), as mentioned in the constructivism approach to decision-making (Landry, 1995; Tversky & Kahneman, 1985). Therefore, these values and interests seem to be in line with the participatory practices developed in this Ph.D. research. A perspective on this work could be to apply the introduced approaches, prototypes, concepts, and notions to a process where urban dwellers are already empowered, i.e., in the higher rung of the ladder of citizen participation (Arnstein, 1969). My research could be applied within bottom-up processes to assess if the findings would apply to this different perspective.

Moreover, my Ph.D. research focuses on urban participatory planning. Urban landscapes are specific, with their tall buildings, high-density, and human-made structures. The adoption of 3D mediums in this urban context is pertinent, but it is not the only context where 3D can be relevant. 3D mediums can also be considered for rural and natural landscape planning or underground conditions. These topics of interest have partially been explored in the literature (Manyoky et al., 2015; Neuenschwander et al., 2014; Wissen Hayek & Grêt-Regamey, 2021). These other planning contexts are relatively similar to urban landscape conditions. Therefore, the approach outlined in this research could be applied to these different settings.

Planning support systems are increasingly more reliable and gradually more based on automated or semi-automated methods that output various planning alternatives (Brasebin et al., 2016; Schüler et al., 2018). Despite the implementation gap (Jiang et al., 2020; Punt et al., 2020), technological approaches to planning are increasingly adopted. The alternative scenarios produced by these automated approaches (which often use machine learning) could be included and discussed in participatory approaches, which could lead to improving the proposed scenarios in collaboration with the population. VGE (and the developed prototypes) could be a valuable visualization support for the scenarios and a suitable medium to stimulate the discussions within the interactive sessions. Furthermore, considering the integration of different technological solutions, Civic Tech and GovTech are currently using digital tools that are limited in terms of functionalities. Therefore, it would be relevant to investigate how the findings of this Ph.D. research could complete existing Civic Tech and GovTech mechanisms and tools without integrating the developed prototypes into a new Civic Tech/GovTech solution. This suggestion could help to reduce the current diversity of digital tools and facilitate their selection.

Participants:

The COVID-19 pandemic affected the practices of participation as well as the urban dwellers. The enforced social distancing in numerous countries strongly affected social interactions. The institutions tentatively implemented online (thus digital) approaches during this period. However, the resulting interactive sessions were perceived as unproductive with only a handful of participants. Following the lifting of the sanitary restrictions, practitioners and participants are pleased to reconnect with face-to-face interaction. Nonetheless, evidence suggests that switching to fully digital participation initiated a transformation toward new participatory approaches. With their enhanced engagement and as facilitators to understanding complex aspects of urban projects, the 3D mediums could support this gradual transition to digital participation.

The participatory approaches that have been mentioned in my research are related to the active involvement of citizens, which may not be willing to participate. However, most of these citizens daily contributes to their favorite network. Therefore, the institution has an enormous amount of information (big data) that they could leverage in order to improve their participatory approach. The data already uploaded in the Web (namely digital trace), could help in the diagnosis of a project by understanding the history, stories and ambiance of a place (building a tacit knowledge) before the beginning of an official participatory approach. The use of machine learning could help to collect and classify this type of data. Furthermore, the tacit knowledge could be used as a first input for an interactive session where the participants could respond to the trends highlighted by the passive data.

3D medium:

As mentioned in the limits section of this Ph.D. research, the developed prototypes were based on abstract visualizations that used Swisstopo 3D objects. Therefore, the virtual environments in which the participants were immersed were limited to yellow and red buildings, unspecific trees, and the objects of the projects. However, an urban landscape's evaluation and significance are substantially more complex than the integrated virtual elements (Matsuoka & Kaplan, 2008; Priego et al., 2008; Vejre et al., 2010). The raw aspect of the 3D visualizations presented in the prototype can hinder the participants' judgments or emotional responses, which could lead to affecting the participatory approach outcomes. One suggestion could be the integration of realistic aspects (linked to emotion) in the prototype, such as photo-realistic representations, street furniture items, or animated characters or vehicles. These additional virtual objects could create improved living VGE, which could enhance the engagement of the population and stimulate more meaningful contributions. These improvements can be supported by recent development in Building Information Modeling (BIM) (and its GIS counterpart, i.e., the City Information Modeling), Digital models (also called Digital Twin), or video game engines.

Moreover, the increasing adoption of digital participatory tools aims at broadening participation, i.e., participants are gradually more involved, which leads to more contributions. However, there is a gap between the collected data through interactive sessions and its interpretation to mindfully contribute to decision-making and planning. The analysis of participatory data is indeed complex and often overlooked, but crucial for the second translation step of the participatory approaches (i.e., addressing the needs of the decision maker, Figure 6.6). In order to facilitate this step, Machine Learning (ML) and more precisely Natural Language Processing (NLP) could simplify this analysis. Some mechanisms promoted by NLP such as tokenization and sentiment analysis can, where subjects raised by the participants can be automatically segmented and identified in addition to the sentiments (positive, negative, or specific emotions) that are related to the subject. Therefore, an NLP approach could accelerate and simplify the analysis of the participatory data, which could hypothetically be added to a dashboard practically in real-time.

12.5. Final remarks

I would like to conclude this manuscript by discussing a recent publication from the consulting firm McKinsey, which shared the technology trends outlook for 2022[47] on August 24th (Figure 12.1). A total of 14 technologies have been highlighted by McKinsey as significant for future development in the industry. Half of these technologies could be pivotal in the next years for urban participatory planning. These technologies are:

- Applied AI, which could be adopted for analyzing the data from participatory approaches (as mentioned here before), but also to help practitioners in the design of participatory planning, or urban experts in the creation of optimized real estate projects.

- Advanced connectivity, which is related to an increase of bandwidth (5G, 6G) allowing the citizens to be involved everywhere without having to worry about internet connection. This advanced connectivity is, therefore, relevant for the implementation of the last prototype. This technology trend is also related to the internet of things that may bring new opportunities for the involvement of the population, such as a public place that is already connected, which allows citizens to digitally contribute to a participatory activity without having to carry any device.

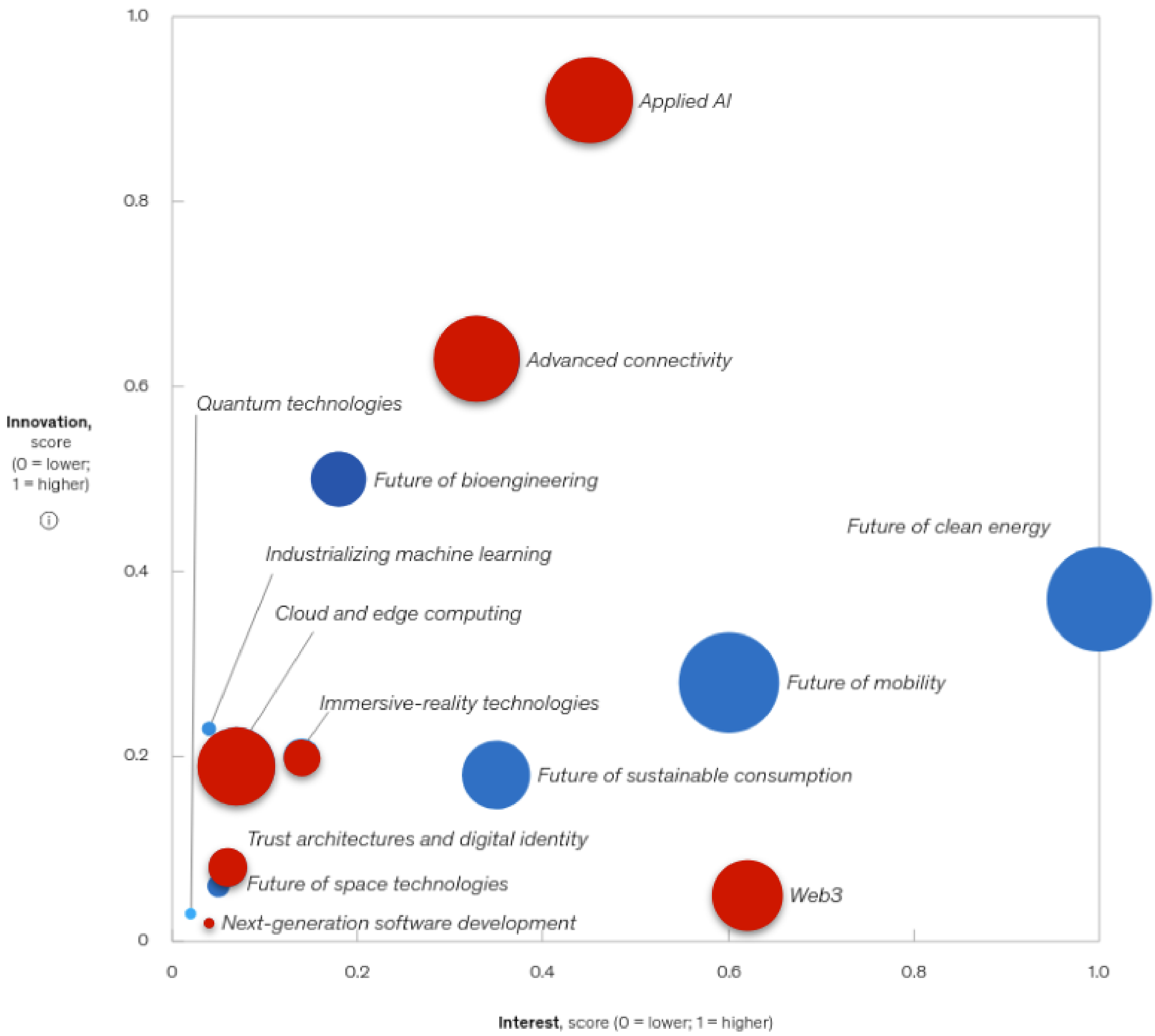
- Immersive-reality technologies, which have already been mentioned in this research. These technologies could help the immersion of the participants in a future urban project and, therefore, facilitate the understanding of complex components of the project.

- Cloud and edge computing is related to the analysis of increasingly important participatory contributions (using algorithm already present in the cloud) and the creation of scalable participatory tools according to the demand.

- Trust architectures and digital identity, notably with blockchain technology, could contribute to the legitimacy of the data collected and the participatory applications promoted by the institution. The contributions of the participants could be executed through a blockchain transaction. This transaction could verify the identity of the participant and the application, the location of the participation, and could encrypt the contribution with these metadata.

[47] https://www.mckinsey.com/capabilities/mckinsey-digital/our-insights/the-top-trends-in-tech

- <u>Web3 and next generation software development</u>, which facilitate the development and implementation of digital tools. Therefore, the authorities that lack the resources could simply create participatory approaches adopting digital technology.



***<u>Figure 12.1</u>**. McKinsey Technology Trends Outlook 2022, the technologies relevant for urban participatory planning are portrayed in red*

A. Appendix A: Towards the Use of a 3D Virtual Globe to Support Public Participatory Decision-Making

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Publication and personal contributions

Chassin, T., Ingensand, J., & Joerin, F. (2018). Towards the use of a 3D virtual globe to support public participatory decision making. In Proceedings of the 21st Conference on Geo-information science - AGILE 2018, Lund 12-15 June, Sweden.

Personal contributions: formulation of research goals and aims, development and design of methodology, software development; designing web application, analyzing and synthesizing study data, figures preparation, manuscript writing.

A.1. Abstract

Today the utilization of 3D mock-ups is very common in GIScience. Since 2001, with the emergence of Google Earth, citizen have become used to virtual globes. However, a majority of applications using these technologies are still restricted to professional users. This is the case with urbanism and decision-making where only static 3D scenes are shared with the public. In this paper, we describe the early results of a 3D virtual globe platform to support participatory decision-making processes for urban planning. Our concept is built on the visualization of specific scenes. Context, content and design are crucial elements that need to be considered for the development of any participatory decision-making tool. Our goal is the development of a web-based platform that focuses on collecting feedback from real-world citizen. The next step of this project is to utilize the platform in a real-world scenario and to evaluate the feedback from real-world citizen.

A.2. Introduction

The establishment and utilization of 3D mock-ups is a common task in the fields of architecture, urbanism, and GIScience. In recent years, large quantities of 3D mock-ups have been created using (semi-) automated methods. Virtual web-based globes and BIM (Building Information Modeling) seem to accelerate this trend with the abundance of new solutions. However, the utilization and the visualization of 3D mock-ups are today mostly restricted to expert users. Especially within the context of spatial planning, 3D mock-ups are clearly underused for decision-making. The goal of this project is the democratization and the utilization of 3D mock-ups in the context of decision-making processes.

The utilization of spatial technologies for participatory decision-making is a concept that has existed since the late 1990'ies. Since then Public Participation GIS (PPGIS) has enabled citizens to participate in decision-making processes. Today web-based web-globes are emerging systems. These systems offer an interactive visualization of 3D objects such as terrain models or buildings in a web browser.

The goal of this paper is to present the first stage of a 3D virtual globe to support public participatory decision-making in Switzerland. Foremost, a review of related work will be presented. Then, we will describe our approach to apprehending the subject. Finally, we will describe the prototype derived from our considerations.

A.3. Related Work

According to Marzouki, Mellouli, & al. (2017), challenges regarding the participation of citizens can be classified into six categories: ethical, efficiency and cost-effectiveness, political, quality, citizens and technology. Technology and more precisely spatial technologies for urban planning have been used for several years. The benefits of 2D maps are engraved in public participation processes (Al-Kodmany, 1999; Rinner, 2001). The issue of citizen empowerment in participatory decision-making dates back to (Arnstein, 1969), who suggests the “ladder of citizen participation”, where 8 rungs are divided into 3 degrees: non-participation, tokenism, and citizen power. He demonstrates that depending on the participation process, the public gets more or less weight in the decision-making process. In 2014 the international association for public participation (iap2) describes a modern public participation spectrum that involves five stages: inform, consult, involve, collaborate, and empower. Every step marks a forward leap regarding citizen influence on the project. At first, authorities intend to notify citizens about the relevant parameters of the project; at the last rung, it is the public who defines the strategy and makes all the decisions regarding the project.

The transition to the third dimension started in 2001 with the emergence of Google Earth. In their state of the art, (Biljecki et al., 2015) identify 29 different categories of scenarios for using 3D city models. Urban planning is one of them, with various outputs such as park design or traffic simulation. However, participatory decision-making is not mentioned as a category.

Notwithstanding, few implementations of 3D tools for public participation have been created. For instance, a European program, IpCity has brought together researchers from several Universities to work on mixed reality (MR) concept. A MR tent, a ColorTable, and a CityWall were developed within this project (Wagner, Broll, & al., 2009). Some web platforms use 3D as visual support for information and public consultation (Alatalo et al., 2017). Others focus on collaboration by adding real-time meeting functionality for authorities/experts and citizens (Hu, Lv, & al. 2015).

A.4. Research Questions and Approach

We were influenced by two studies that aimed at describing guidelines for participatory processes. (Lovett et al., 2015) recommend answering three concerns, 1) when? 2) what? 3) how? The first point is about the general context and history of the area as the definition of the participants, the resources, and the purpose. The second aims at defining the contents such as the realism (verism vs sketch) and the features. The last issue intends to clarify the visualization and methods used for implementing interactivity. In their research, Bryson, Quick, & al., (2012) provide an akin approach split into three axes. The starting phase established the purpose and the context (when?). The next stage describes the resources and the participation handling (what? how?). The last step computes the results and enhances the process. The overall concept is to continuously improve public participation.

A.4.1. Concept

The utilization of 3D mock-ups on the Internet in the context of decision making processes for spatial planning is a sensitive subject and several points need to be considered.

what*?* - A mock-up needs to be understandable. This point suggests that the visualization of a virtual mock-up needs to be as objective as possible in order to allow the user to understand the impact of a future building or neighborhood. This implies research in the domain regarding the spatial cognition of 3D mock-ups and visualization aspects such as the Level of Detail (LOD), the objects to be visualized (existing objects and new objects), the choice of colors and textures, and navigation tools in the mock-up (e.g. authorized points of view). Some clues about contents and their representation as objects or as surroundings have been described by Brasebin, Christophe, & al. (2016).

how*?* - The 3D mock-up needs to be utilized within a decision-making process. This implies that alternatives need to be evaluated and compared based on criteria that indicate the consequences for each alternative. A system that includes a mock-up needs to offer possibilities to give feedback. Therefore, different means for a citizen to give feedback regarding a project within the context of spatial planning need to be identified and discussed. The word e-planning is increasingly used for describing this kind of tool, which collects a tremendous amount of functionality borrowed from the web 2.0 such as evaluation, modification, sketching, sharing, tagging, etc (Steiniger, Poorazizi, & al. 2016).

when? - A 3D spatial decision-making system needs to be part of a political process. In Switzerland for instance decision-making processes are well-structured and well defined. A challenge is, therefore, to identify the best moments and channels to utilize a 3D spatial decision-making system within a decision-making process. Apart from political processes, the citizen's background related to the surroundings often represents tacit (unsaid) knowledge that needs to be taken into account for the development of a 3D participatory platform.

A.4.2. Hypotheses

The utilization of Web 2.0 functionalities focuses on the exchange between users and the 3D mock-up as tangible visual support for argumentation, hence we can establish the hypothesis that such a tool will enhance the communication and the debate between citizens (**H1**). Moreover, the planning of a project will be discussed ahead using such tools and the citizens will be engaged in the decision-making process. We, therefore, assume that a project's acceptance rate will increase and the proportion of opposition will decrease (**H2**).

New media to advertise public participation processes such as social networks reach many people, however, one of the main drawbacks of this kind of media is to transform citizens' enthusiasm into action (Evans-Cowley, 2010). The utilization of a 3D web tool will ease the current process complexity (public meetings) and boost public society participation (**H3**). Besides, the esthetic rendering and the use of social networks will further increase the ratio of younger people in such discussions, currently rarely present at public events. Older people are already involved in participatory processes and should adopt such tools smoothly using appropriate communication channels (**H4**).

A.5. Prototype

Our development process is based on an iterative improvement loop. Figure A.1 highlights two distinct phases. The first phase is the "action" stage in blue where we implement our solution in real-world city projects. Its two substages are the implementation of real-world use cases in the tool and the use of the tool with the users. The second phase is the "improvement phase" where we first analyze feedback from the use case, then we develop functionality or improve elements that what do not meet the users' expectations.

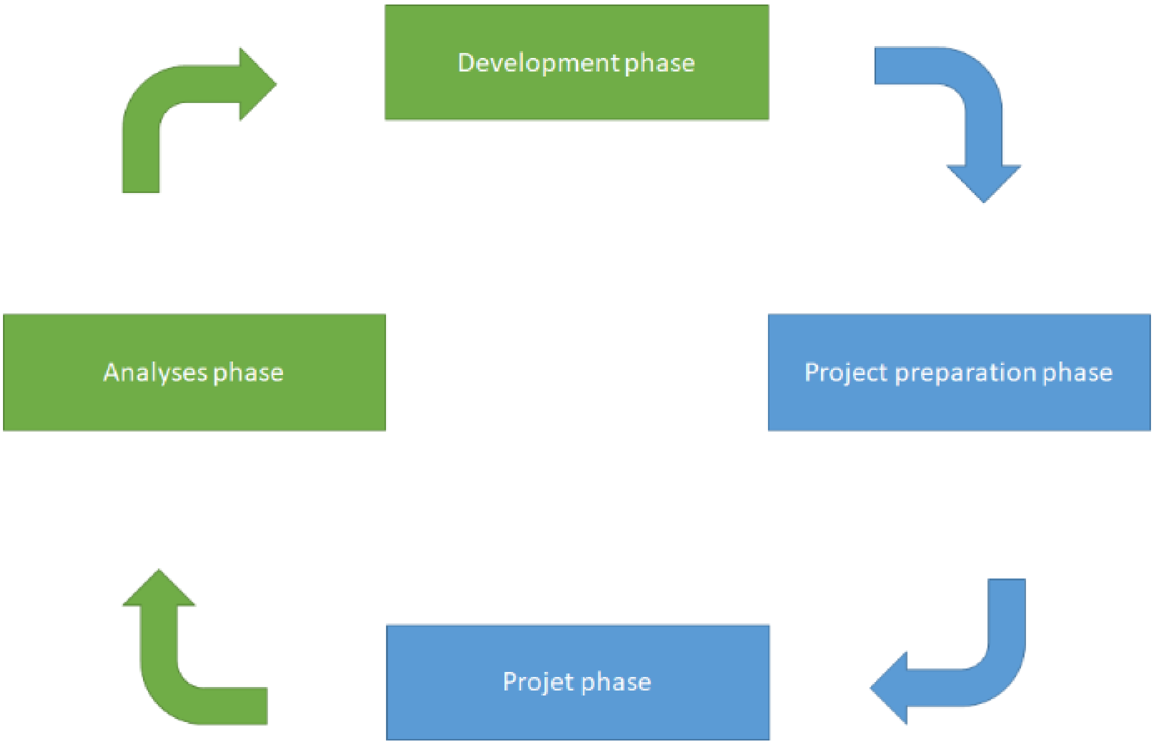

***Figure A.1**. Iterative development process*

Currently, we are in the first phase of development. Thus, this section will present our choices regarding the technical implementation and what drove them, then in a second part, we will present some early results.

A.5.1. Technical Implementation

A.5.1.1. Technical Choices

Cesium (cesiumjs.org) was chosen for the 3D rendering. This high level API is quoted many times in the literature, (Schaik, 2010; Blut, Blut, & al. 2017), and described as an efficient solution which can stream a considerable load of data (Cesium 3D Tiles), natively supports OGC services, and handles all coordinate systems in real-time (Krämer & Gutbell, 2015). Furthermore, this virtual globe technology develops a simple to use, a client-side tool which meets our two main goals.

We have combined this 3D rendering engine with a form-efficient framework, Vuejs. The application runs on a node js server and is linked to a geographical relational database, PostgreSQL/PostGIS (postgresql.org).

A.5.1.2. Data Sets

Datasets are mainly provided by SwissTopo (swisstopo.admin.ch) through web services: DEM, orthophotos, and 3D models (buildings and trees). These layers are streamed in real-time via Cesium 3DTiles (Fig. A.2). The application is based on context pictures from Flick services (flickr.com), loaded only within a 2 kilometers perimeter from the user's camera. These data sets ease the creation of the surroundings of the scene, aiming to integrate all landmarks needed by the users to relate the model to the real-world.

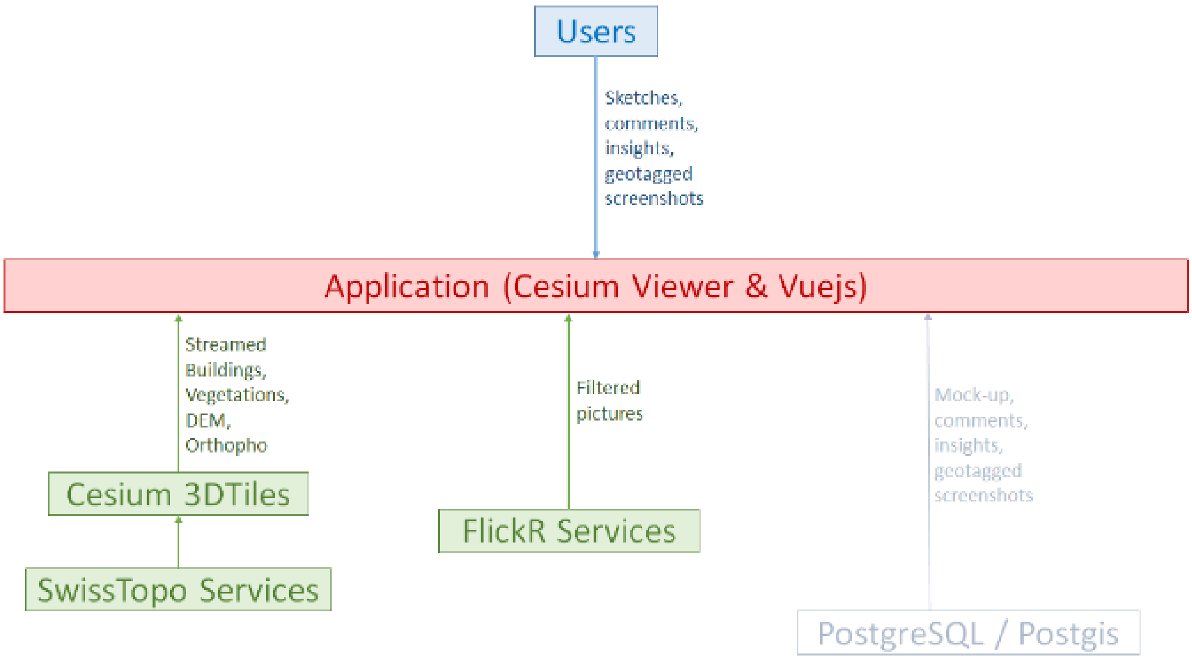

Figure A.2. *Data Flow.*

Users can contribute with data as well and manually add objects such as screenshots, sketches and insights.

A.5.2. Web User Interface

One challenge is the question of how to place the user in the center of the discussion. Currently, a majority of participatory decision-making initiatives appear to consider citizens as observers. In this case, we can talk of communication or information processes. Our goal on the other hand is to create a debate between public society and authorities.

In the following section, we will describe the implementation of our 3D platform.

A.5.2.1. Interface

GIS solutions are often regarded as professional tools, and can repel shareholders. Therefore, we aim at developing a user-friendly interface. When a user logs in, the only visible features are the bottom left menu and the 2D bottom right maps with some useful action shortcuts.

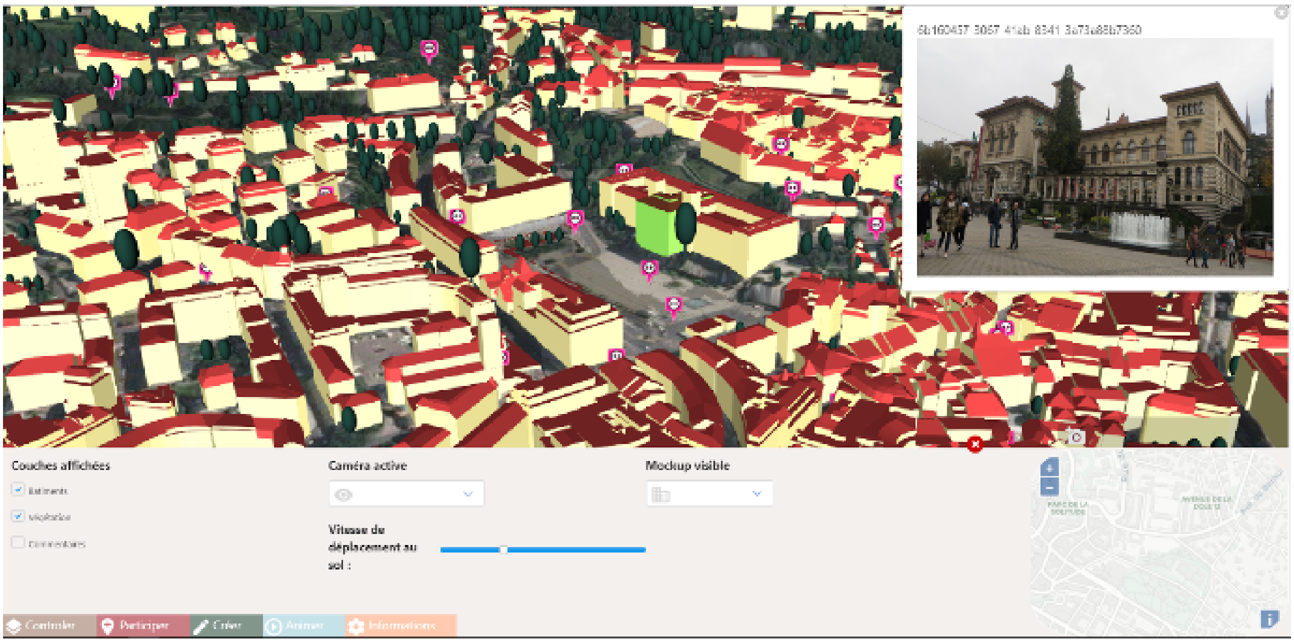

Figure A.3. *Example of the bottom menu and the tacit knowledge.*

The bottom panel is activated in the menu. This layout has been inspired by modern city building simulation games such as City Skyline or SimCity. It has two benefits, at first, the bottom panel breaks with common GIS solutions such as ArcGIS (esri.com) or QGIS (qgis.org). Secondly, screens are horizontally larger than vertically and therefore offer more space for the interface's features. (Fig. A.3).

In the bottom right corner, 2D maps enable to pinpoint the user camera position; the maps are oriented to match the camera's direction. Three shortcuts, "take a screenshot", "add a comment", and "answer the survey" are situated above the map.

A.5.2.2. Navigation

According to Montello (1993) the perception of surroundings is strongly affected by scale; in his study, four scale categories are suggested, Figural, Vista, Environmental and Geographical. Urban planning stands between the Vista space (an object that is the same size or slightly bigger than a human body such as a building or a square), and the Environmental space (a place that cannot be apprehended from a standing position such as a district). To enable users to understand the 3D virtual environment, we have developed four distinct cameras or navigation possibilities. Jankowski & Hachet (2015), described in an article resuming different studies, an entire bundle of 3D interactions. From this review, we choose to implement two cameras allowing to handle the Vista space. One is derived from the *specified coordinate movement* (Jankowski & Hachet, 2015), where some coordinates are pre-computed in the application. Users can choose different positions and look around from this point of view. Two degrees of freedom (DOF) are allowed. Movements are vertically blocked between -60° and 60° to mimic the human head. The other, the *specified trajectory movement* is an automatic displacement of the camera between points of interests without user interaction. The environment scale is managed via a walking and a flying camera. The user has full control of his movement, and the walking camera (first-person perspective) is clamped to the ground with four DOFs. The three DOF flying movements are handled via rotations.

A.5.2.3. Features

<u>Control</u>: In this tab, classic GIS functionality is regrouped. Users can display or hide context layers (buildings, trees, Flickr pictures) and points of interest defined by other users. Camera preferences are settable from this tab, speed of movement and type. If different proposals are provided by the stakeholders, users can choose to visualize these proposals via mock-ups in the 3D virtual environment, as shown in Figure A.4. This component allows citizens to step inside a scaled environment without any perspective bias induced by static pictures created by opponents or supporters of a specific proposal.

Figure A.4. *Interactive Comparison between two mock-ups*

<u>Participation</u>: This tab aims at gathering functionality related to participation such as real-time discussions or the establishment of geo-referenced screenshots. Our goal is to promote discussion and exchange between users. Each comment can be answered, tagged, and rated. At any moment, users can take a geo-referenced screenshot of their current view and add a description. Once finished, their picture is published as a pin on the map. Other users are allowed to comment and rate the screenshot. One contribution to decision-making is the insight component. Urban planning professionals such as architects prefer having inspirational pictures at hand during the prototyping phase of a project. We decided to implement the same functionality. A bucket of pictures is selected and added as a layer to the 3D scene. A user is able to translate, rotate, enlarge or choose the degree of transparency of a photo (Fig. A.5). A tag system allows for ordering, classifying, and rating the usefulness of the pictures.

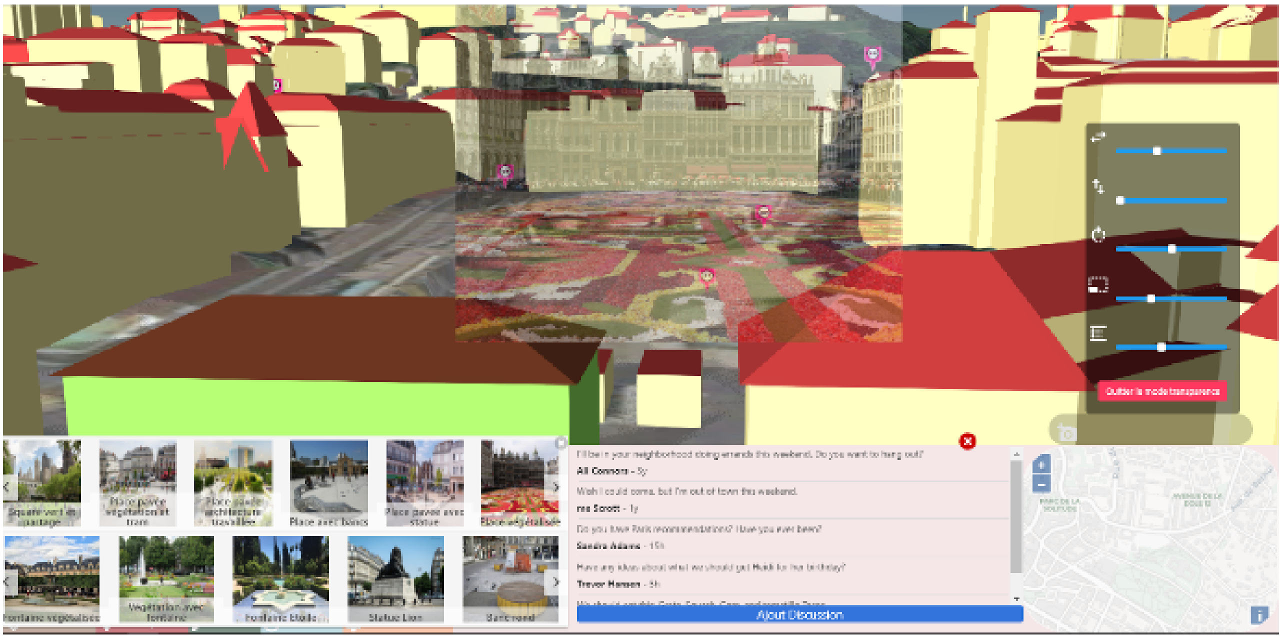

Figure A.5. *Semi-transparent insights integrated in the 3D scene.*

Creation: This tab aims at encouraging citizens to create sketches. A tool allows for drawing 2D points, lines, and polygons directly in the scene. Predefined 3D components such as a house, a bench, or a tree can be added to the scene.

Animation: In this tab, two sets of functionality are put together. First, two sliders allow any user to control the position of the sun (date, hour) and to identify areas affected by shadows. Moreover, an animation launcher starts a specified trajectory movement of the camera with a simulation of the sun's position moving over time.

A.6. Conclusions and Perspectives

In this article we have introduced the establishment of a 3D platform to support public participation. This platform focuses on citizens' contributions such as comments, insights, and screenshots. Another key element of this tool is the ability to add and represent tacit knowledge in 3D through pins. Our method for the implementation of this tool is an iterative process involving two phases: project testing and improvement.

Our next steps are to complete the development of the application in order to quickly use it in the context of a real-world scenario in Switzerland. Furthermore, we want to utilize this experience to validate our hypotheses that address H1: *The acceptance of our platform*, H2 *The participation of citizens*, H3 *The utilization of our platform to ease the complexity of current participatory processes,* and H4 *The utilization of the platform by other population groups.*

During the development process, we aim at following the *when - what - how* guidelines and staying focused on the context, the content, and the design.

As a perspective of this study, we are considering the concept of an *urban promenade* where a group of citizens is guided by a mentor along a path of interest. In this concept, each stop is marked by descriptions, pictures, and explanations of a future project. Another perspective is to use augmented reality technologies during these promenades to allow the participants to discover the scene by themselves.

B. Appendix B: Action-Research: Assessment on Using a 3D Participatory Platform for Reviewing a Swiss City Urban Development Plan

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B.1. Abstract

The revision of a city's Master Plan is a crucial step for its urban future development. Engaging citizens in its elaboration could increase its acceptance and understanding by the public. In this study, we suggest to use a 3D participatory digital platform to improve public engagement. In our 3D virtual platform, citizens were able to share their preferences about various city places. However, the authorities requested to abandon the 3D representation in favor of a 2D portrayal. Our conclusion regarding this decision is a distorted knowledge about 3D and a favored practice of 2D maps.

B.2. Introduction and Case Study

The Master Plan (MP) of a city aims to categorize the areas to be built, enhanced, and conserved. In the current urban context, where the need to density cities is recognized but often opposed by citizens; the revision of the MP is a key issue. The Swiss city discussed in this study decided to engage its citizens in this complex task in order to increase public acceptance. Since the MP is a rather technical document, a light version of this plan was used as the starting point of a participatory process. The authorities' request was to identify areas of controversy and to compare citizens' insights with those of urban experts.

B.3. Methodology and Prototype

The key point of the discussions with the authorities was to define the presentation of the aspects of the MP to the public. A 3D participatory platform was suggested to collect and to identify information about the perception of the city by the public. A two-phase scenario for the utilization of the platform was created in order to support the users throughout their interaction with the platform. First, users had to pinpoint places where they usually go using the 3D virtual environment (3DVE, also Virtual Geographic Environment), to categorize the place they had selected (street, square, park, building, tree, point of view) and to indicate the frequency they are visiting the place (very often to very seldom). In the second step, the participants had to indicate elements of the city that they appreciate (or not). As in the first step, they had to categorize these locations with the predefined categories and to provide their preferences from "very appreciated" to "not appreciated at all" as well as the reasons for their choice (memory, attraction, animation, noise, etc.). In order to help the users to locate themselves in the 3DVE, an address bar and a 2D map were suggested in the prototype of the platform.

B.4. Results and Discussion

After long discussions, the authorities rejected the proposal. The city demanded to abandon 3D visualizations and to only use 2D maps. An interpretation of this result can be related to a lack of knowledge of participatory processes by the authorities as well as a certain reluctance towards new technologies. Our opinion on the authorities' willingness to adopt 2D rather than 3D is based on two assumptions: The first is about the suggestion of an abstract 3D representation that was not in line with the popular vision of photo-realistic 3D models put forward by video games and architectural mock-ups. The second is related to spatial perception: for the depiction of large areas, a 2D visualization can be better adapted to represent geographical spaces from above, facilitating spatial understanding due to its widespread use and its synthetic view. According to this hypothesis, a solution to this problem could be a system where large areas (city scale) are depicted in 2D, and a transition to 3D is offered once the user reaches smaller scales.

C. Appendix C: Supplementary Materials of Paper A

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Appendix C.1: Description of the Collected Data

In this first appendix, the metadata and the data collected through the study is provided. This data will be published in zenodo but for the revision process, the metadata will be provided in this section, completed by a csv file containing the entire dataset (named articles_description.csv).

Metadata.

- Title: title of the article
- Link: link to recover the articles online. All the links were retrieved at the latest on 01.06.2022. Certain links ask for payment to be consulted
- Words Count: number of words that the article contains
- Body: the body of the article, retrieved from the aggregators (Factiva and Nexis)
- Date of Publication: day, month, and year on which the article was published
- Language: main language employed in the article; [FR: french, EN: english]
- Project Location: location of publication; [city, country identifier in 2 letters]
- x: longitude of the location
- y: latitude of the location
- Same Visual as Article: [yes] if the visual is present in the article (via a link or an image); [recovered] if the visual was recovered from the investigation
- Visual Link: link to the visual. All the links were retrieved at the latest on 01.06.2022.
- Project Stage: stage of the project as described in The stage of the project
- Project Scale: the scale of the project as described in The scale of the project
- Participation Level: level of participation as described in The level of participation
- Technology: technology, which is used to broadcast the visual mention in The format

- Medium: medium used to share the visual (subcategory of technology)
- Interaction Type: type of interaction implement to explore the visual, see The controls
- Visual Goal: the goal of the visual
- Participation Location: location where the visual is consulted (e.g., public hearings, mobile app, workshop)
- Audience: who consulted the visual (e.g., buyers, neighbors, public, officials, professionals)
- Online vs On-site: online settings of the visual [online, on-site]
- Realism: realism of the visual described by (Raaphorst et al., 2018)
- Style: the style of the visual described by (Raaphorst et al., 2018), see The portrayal
- LoD: Level of detail of the depicted project described by (Biljecki et al., 2014), see The portrayal
- Angle of View: angle of view used to represent the project [first-person, Birds-eye-view]
- Model animation: [static] the model is not animated; [animated] the model contain an animation (persons, cars, trains, etc.)
- Representamen: (small) contextual elements represented in the visual in addition to the project such as vehicles, humans, or vegetation
- Detail of Model Surroundings: an additional layer of information present in the visual and their representation (e.g., basemap, realistic/abstract buildings)
- Aggregator: aggregator in which the article was recovered [Factiva, Nexis]

Appendix C.2: Description of the Aggregators' Queries

In this second appendix, all the queries (and their filters) used to recover the articles are described.

French queries.

Search Terms: (concertation OU engagement OU consultation OU information OU participat!) ET (publi! OU citizen! OU citoyen! OU participat! OU civic OU population) ET (maquette OU mod?l! OU virtu?l! OU mock-up! OU mockup!) ET (urban! OU aménagement OU batiment OU projet OU building OU project OU planning OU development OU architectur!) ET 3D SAUF (BIM OU impression OU imprimante OU print!)

Search Type: Terms and Connectors

Narrowed by:

Content Type	**Narrowed by**
News	Type de publication: Newswires & Press Releases,Blogs,Newspapers,News Transcripts,Web-based Publications,Magazines & Journals,Aggregate News Sources,UNDEFINED,News,Newsletters,WebLinks,Video,Audio; Sujet: Science et technologie,Société, aide sociale et style de vie,Tendance et événement; Secteur d'activité: Informatique et technologie de l'information,Média & télécommunication; Langue: English,French; Géographie: Europe,Amérique du Nord; Géographie: Europe; Langue: French

saved (32)

Search Terms: 3D ET (participat* OU coconstruction OU concertation) SAUF imprimante* SAUF impression SAUF cinéma

Search Type: Terms and Connectors

Narrowed by:

Content Type	Narrowed by
News	Langue: French; Chronologie: janv. 01, 2015 au déc. 31, 2021; Type de publication: Newspapers,Newswires & Press Releases,Magazines & Journals,Web-based Publications,Newsletters,UNDEFINED,WebLinks,Blogs,News; Sujet: Gouvernement et administration publique,Sciences sociales,Population & démographie,Science et technologie,Société, aide sociale et style de vie; Secteur d'activité: Informatique et technologie de l'information,Bien de consommation,Média & télécommunication

saved (90)

Text	3D and (participat* or coconstruction or concertation) not imprimante* not impression not cinéma
Date	01/01/2015 à 31/12/2021
Source	Toutes les sources
Auteur	Tous les auteurs
Société	Toutes les sociétés
Sujet	Tous les sujets
Secteur économique	Tous les secteurs économiques
Région	Toutes les régions
Langue	Français
Filtres d'actualités	Secteurs économiques: Not Construction automobile Not Activités en amont : pétrole brut/gaz naturel Not Banques/Organismes de crédit Not Fonds/trusts/instruments financiers Not Transport aérien de passagers Sujets: Not Arts et spectacles Not Sports

saved (377)

English queries.

Search Terms: (“3D geo*visuali*ation” OR "landscape visuali*ation" OR "3D model*" OR "city model*" OR (3D NEAR/3 environment*) OR "virtual geographic* environment*" OR (3D NEAR/3 visuali*ation*) OR (3D NEAR/3 representation*) OR (3D NEAR/3 landscape*) OR "3D web application*" OR "3D web technolog*" OR "geo*visuali*ation*" OR "virtual globe*" OR "virtual landscape*" OR “3D exploration” OR “3D urban model*” OR “3D geomodel*” OR “3D game engine*” OR “urban data visuali*ation” OR “point cloud*” OR “3D scene*” OR “3D urban scene*” OR “digital twin” OR “3D urban space*” OR (3D NEAR/3 reconstruct*) OR “CityGML” OR “CityEngine” OR (3D NEAR/3 geospatial) OR (3D NEAR/3 technolog*) OR (3D NEAR/3 simulation*) OR “3D geo*information” OR “digital earth” OR ("second life" NEAR/3 3D) OR “geo*virtual” OR “3D geodesign”)

Search Type: Terms and Connectors

Narrowed by:

Content Type	**Narrowed by**
News	Timeline: 01 janv. 2015 au 13 oct. 2021; Langue: English; Type de publication: Web-based Publications,Newspapers,News Transcripts,Blogs,Magazines & Journals,Video,Newsletters,News; Sujet: Rapport, critique et rubrique,Science et technologie

saved (54)

Search Terms: (“3D geo*visuali*ation” OR "landscape visuali*ation" OR "3D model*" OR "city model*" OR (3D environment*) OR "virtual geographic* environment*" OR (3D visuali*ation*) OR (3D representation*) OR (3D landscape*) OR "3D web application*" OR "3D web technolog*" OR "geo*visuali*ation*" OR "virtual globe*" OR "virtual landscape*" OR “3D exploration” OR “3D urban model*” OR “3D geomodel*” OR “3D game engine*” OR “urban data visuali*ation” OR “point cloud*” OR “3D scene*” OR “3D urban scene*” OR “digital twin” OR “3D urban space*” OR (3D reconstruct*) OR “CityGML” OR “CityEngine” OR (3D geospatial) OR (3D technolog*) OR (3D simulation*) OR “3D geo*information” OR “digital earth” OR ("second life" 3D) OR “geo*virtual” OR “3D geodesign”) AND (“participa*” OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun*based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR (“participa*” "interacti*") OR ("communit*" "interacti*") OR ("stakeholder*" "interacti*") OR ("resident*" "interacti*") OR ("citizen*" "interacti*") OR (“participa*” "involv*") OR ("communit*" "involv*") OR ("stakeholder*" "involv*") OR ("resident*" "involv*") OR ("citizen*" "involv*")) AND ((“building*” OR "landscape" OR "urban" OR "city" OR "environment" OR "land*use" OR "spatial" OR "town" OR "neighb*rhood" OR "green*space*" OR "green*infrastruct*" OR "green*area*" OR "park*") AND ("planning" OR "design*" OR transform*))

Search Type: Terms and Connectors

Narrowed by:

Content Type	**Narrowed by**
News	Timeline: Jan 01, 2015 to Dec 31, 2021; Publication type: Web-based Publications,Newspapers,Blogs; Subject: Government & Public Administration,Science & Technology,Society, Social Assistance & Lifestyle

saved (84)

Search Terms: (visuali*ation OR virtual*) AND (plan* OR design*) AND (participa* OR communit* OR resident* OR citizen* OR public) AND 3D

Search Type: Terms and Connectors

Narrowed by:

Content Type	**Narrowed by**
News	Publication type: Web-based Publications,Newspapers; Language: English; Subject: Science & Technology

saved (87)

Search Terms: (3D OR "virtual geographic* environment*" OR "virtual globe*" OR "digital twin") AND ("participa*" OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun*based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR ("participa*" NEAR/3 "interacti*") OR ("communit*" NEAR/3 "interacti*") OR ("stakeholder*" NEAR/3 "interacti*") OR ("resident*" NEAR/3 "interacti*") OR ("citizen*" NEAR/3 "interacti*")) SAUF print*

Search Type: Terms and Connectors

Narrowed by:

Content Type	**Narrowed by**
News	Chronologie: janv. 01, 2015 au déc. 31, 2021; Langue: English; Sujet: Gouvernement et administration publique; Secteur d'activité: Informatique et technologie de l'information; Type de publication: Blogs,Web-based Publications,Newspapers

saved (8)

Search Terms: ((3D w/3 visual*) OR (3D w/3 draw*) OR (3D w/3 illustrat*)) AND (("landscape" OR "urban" OR "city" OR "environment" OR "land?use" OR "spatial" OR "town" OR "neighb?rhood" OR "green?space*" OR"green?infrastruct*" OR "green?area*" OR "park*") AND ("planning" OR "design*")) AND ("participa*" OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun?based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR ("participa*" NEAR/3 "interacti*") OR ("communit*" w/3 "interacti*") OR ("stakeholder*" w/3 "interacti*") OR ("resident*" w/3 "interacti*") OR ("citizen*" w/3 "interacti*"))

Search Type: Terms and Connectors

Narrowed by:

Content Type	**Narrowed by**
News	Chronologie: janv. 01, 2015 au déc. 31, 2021; Type de publication: Newspapers,Web-based Publications,Blogs

saved (19)

Text	(3D OR "virtual geographic* environment*" OR "virtual globe*" OR “digital twin”) AND (“participa*” OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun*based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR (“participa*” NEAR/3 "interacti*") OR ("communit*" NEAR/3 "interacti*") OR ("stakeholder*" NEAR/3 "interacti*") OR ("resident*" NEAR/3 "interacti*") OR ("citizen*" NEAR/3 "interacti*"))
Date	01/01/2015 à 31/12/2021
Source	Toutes les sources
Auteur	Tous les auteurs
Société	Toutes les sociétés
Sujet	Tous les sujets
Secteur économique	Technologie ou Immobilier/Construction
Région	Toutes les régions
Langue	Anglais
Filtres d'actualités	Secteur économique: Not Impression 3D et 4D Sujet: Not Informations sociétaires et industrielles

saved (110)

Text	(“3D geo?visuali?ation” OR "landscape visuali?ation" OR "3D model*" OR "city model*" OR (3D w/3 environment*) OR "virtual geographic* environment*" OR (3D w/3 visuali?ation*) OR (3D w/3 representation*) OR (3D w/3 landscape*) OR "3D web application*" OR "3D web technolog*" OR "geo$visuali?ation*" OR "virtual globe*" OR "virtual landscape*" OR “3D exploration” OR “3D urban model*” OR “3D geomodel*” OR “3D game engine*” OR “urban data visuali?ation” OR “point cloud*” OR “3D scene*” OR “3D urban scene*” OR “digital twin” OR “3D urban space*” OR (3D w/3 reconstruct*) OR “CityGML” OR “CityEngine” OR (3D w/3 geospatial) OR (3D w/3 technolog*) OR (3D w/3 simulation*) OR “3D geo?information” OR “digital earth” OR ("second life" w/3 3D) OR “geo?virtual” OR “3D geodesign”) AND (("landscape" OR "urban" OR "city" OR "environment" OR "land?use" OR "spatial" OR "town" OR "neighb?rhood" OR "green?space*" OR"green?infrastruct*" OR "green?area*" OR "park*") AND ("planning" OR "design*")) AND (“participa*” OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun?based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR (“participa*” NEAR/3 "interacti*") OR ("communit*" w/3 "interacti*") OR ("stakeholder*" w/3 "interacti*") OR ("resident*" w/3 "interacti*") OR ("citizen*" w/3 "interacti*"))
Date	01/01/2015 à 31/12/2021
Source	Toutes les sources
Auteur	Tous les auteurs
Société	Toutes les sociétés
Sujet	Tous les sujets
Secteur économique	Tous les secteurs économiques
Région	Toutes les régions
Langue	Anglais
Filtres d'actualités	Sujet: Not Informations sociétaires et industrielles

saved (126)

Text	((3D w/3 visual*) OR (3D w/3 draw*) OR (3D w/3 illustrat*)) AND (("landscape" OR "urban" OR "city" OR "environment" OR "land?use" OR "spatial" OR "town" OR "neighb?rhood" OR "green?space*" OR"green?infrastruct*" OR "green?area*" OR "park*") AND ("planning" OR "design*")) AND (“participa*” OR "communit*" OR "collaborat*" OR "stakeholder*" OR "commun?based" OR "resident*" OR "citizen*" OR "human-cent*" OR "people-cent*" OR "people-driven" OR "people-led" OR "e-participa*" OR "e-govern*" OR "communicat*" OR (“participa*” NEAR/3 "interacti*") OR ("communit*" w/3 "interacti*") OR ("stakeholder*" w/3 "interacti*") OR ("resident*" w/3 "interacti*") OR ("citizen*" w/3 "interacti*"))
Date	01/01/2015 à 31/12/2021
Source	Toutes les sources
Auteur	Tous les auteurs
Société	Toutes les sociétés
Sujet	Tous les sujets
Secteur économique	Tous les secteurs économiques
Région	Toutes les régions
Langue	Toutes les langues

saved (14)

Text	(concertation or consultation or information or publique or public or citizen* or citoyen* or participat*) and (maquette or mod?l* or virtu?l*) and (urban* or aménagement or batiment or projet or building or project or planning) and 3D not (BIM or impression or print*)
Date	01/09/2021 à 31/12/2021
Source	Toutes les sources
Auteur	Tous les auteurs
Société	Toutes les sociétés
Sujet	Tous les sujets
Secteur économique	Tous les secteurs économiques
Région	Toutes les régions
Langue	Toutes les langues
Filtres d'actualités	Société: Not National Natural Science Foundation of China Secteur économique: Not Extraction de minerai d’or Sujets: Not Informations sociétaires et industrielles Not Crimes/Tribunaux Not Epidémies Sources: Not CE NoticiasFinancieras (Latin America) Not Federal Register (U.S.) Not NewsRx Medical Newsletters - All sources Not PR Newswire - All sources Not Dow Jones Newswires - All sources Not Public Companies News and Documents via PUBT Langue: Not Portugais Not Espagnol

saved (28)

French + English queries.

Text	(concertation or consultation or information or publique or public or citizen* or citoyen* or participat*) and (maquette or mod?l* or virtu?l*) and (urban* or aménagement or batiment or projet or building or project or planning) and 3D not (BIM or impression or print*)
Date	lors des 5 dernières années
Source	Toutes les sources
Auteur	Tous les auteurs
Société	Toutes les sociétés
Sujet	Tous les sujets
Secteur économique	Tous les secteurs économiques
Région	France ou Suisse
Langue	Français ou Anglais

saved (262)

Text	(concertation or consultation or co-construction or participat*) and (publique or public or citizen* or citoyen* or population) and (maquette or mod?l* or virtu?l*) and (urban* or aménagement or batiment or projet or building or project or planning) and 3D and (futur* or new or nouveau) not (BIM or impression or imprimante or print*)
Date	01/01/2015 à 31/12/2020
Source	Toutes les sources
Auteur	Tous les auteurs
Société	Toutes les sociétés
Sujet	Résumé des informations ou Prospectus ou Liens audio-visuels ou Interviews ou Informations générales ou Images ou Extraits ou Enquêtes/Sondages ou Editoriaux ou Critiques ou Conseils ou Communiqués de presse ou Commentaires/Opinions ou Blogs ou Articles à la Une ou Analyses ou Agendas ou Education ou Immobilier/Maison ou Mode de vie ou Société/communauté ou Transport ou Commentaires et conseils d'experts ou Conférences et expositions ou Environnement/Social/Gouvernance ou Gestion des connaissances et de l'information ou Innovations commerciales/de rupture ou Législation et politique gouvernementale ou Numérisation ou Partenariats/Collaborations ou Recherche et développement ou Sociétés - Modifications et changements ou Technologie de l'information ou Top News
Secteur économique	Tous les secteurs économiques
Région	Toutes les régions
Langue	Français ou Anglais
Filtres d'actualités	Sociétés: Not DBS Bank Ltd Not GoGold Resources Inc. Not Environmental Protection Agency Not National Marine Fisheries Service Not Monetary Authority of Singapore Not U.S. Fish and Wildlife Service Not US Securities and Exchange Commission Not Union Européenne Not Vermilion Energy Inc. Source: Not Federal Register (U.S.)

saved (77)

D. Appendix D: Supplementary Materials of Paper D

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D.1. Models Creation & Publication

The design and publication of the VGE were subject to two requirements: the study's easy access from a multitude of material settings and bandwidths, and the creation of similar 3D scene layouts. To meet these conditions, we designed the 3D scenes following four steps: (1) collection of 2D footprints, via the manual screening of various cities in OpenStreetMap (OSM); and the extraction of different, but similar district footprints of about 30 buildings; (2) the cleaning of the raw data, with the importation of the footprints in Blender (3D software), and the decluttering of the raw data from OSM from 30 buildings to an average of 17 carefully selected buildings; (3) creation of the 3D models, via the extrusion of the edifices, and the shaping of the roof according to satellite imagery; and (4) coloration of the buildings, with the draping of the textures on the surface (wall and roof). The photo-realistic textures were recovered from surveying pictures of facades. To limit the overload of information within the VGE, we did not add contextual elements, such as vegetation, urban furniture, roads, or traffic. Once created, we imported the scenes into a web application via Three.js, a 3D JavaScript library based on WebGL. To the best of our knowledge, no ready-made survey solution has been able to include an interactive 3D section. Therefore, we published this study through an in-house solution.

The VGE are published on Zenedo, doi: 10.5281/zenodo.5137307.

The in-house code used in this study is under MIT license available on github: https://github.com/thibaud-c/3DperceptionUX.

D.2. Detailed Statistical Tables

Inputs Count

The values depicted in this table are used in section 4.1.1. *Impact of the VGE representations on user performance* and section 4.1.2. *Impact of the metaphors on user performance*.

	LoD 1 + Color	LoD 2 + Texture	LoD 2 + Focus	LoD 2 + Color
Memory	$W_U = 2.418$ $p = 0.016$ $p_{BH} = 0.052$	$W_U = 2.798$ $p = 0.005$ $p_{BH} = 0.026$	$W_U = 1.546$ $p = 0.122$ $p_{BH} = 0.244$	$W_U = 3.092$ $p = 0.002$ $p_{BH} = 0.020$
LoD 2 + Color	$W_U = -0.748$ $p = 0.454$ $p_{BH} = 0.568$	$W_U = 0.540$ $p = 0.589$ $p_{BH} = 0.654$	$W_U = -1.629$ $p = 0.103$ $p_{BH} = 0.244$	
LoD 2 + Focus	$W_U = 0.829$ $p = 0.407$ $p_{BH} = 0.568$	$W_U = 1.146$ $p = 0.252$ $p_{BH} = 0.420$		
LoD 2 + Texture	$W_U = -0.172$ $p = 0.864$ $p_{BH} = 0.864$			
First 4 Batches	$KW_H = 2.776$ $p = 0.427$			
First 4 Batches + Memory	$KW_H = 12.058$ $p = 0.017$			

KW_H : Kruskal-Wallis test; W_U: Wilcoxon rank-sum test; p: p-value;
p_{BH}: false discovery rate correction (Benjamin-Hochberg procedure)

Completion time

The values depicted in this table are used in section 4.1.1. *Impact of the VGE representations on user performance* and section 4.1.2. *Impact of the metaphors on user performance*.

	LoD 1 + Color	LoD 2 + Texture	LoD 2 + Focus	LoD 2 + Color	Memory
Static	$W_U = -6.070$ $p < 0.001$ $p_{BH} < 0.001$	$W_U = -3.864$ $p < 0.001$ $p_{BH} < 0.001$	$W_U = -6.918$ $p < 0.001$ $p_{BH} < 0.001$	$W_U = -4.348$ $p < 0.001$ $p_{BH}\ 0.001$	$W_U = -0.873$ $p = 0.383$ $p_{BH} = 0.410$
Memory	$W_U = -5.556$ $p < 0.001$ $p_{BH} < 0.001$	$W_U = -3.108$ $p = 0.002$ $p_{BH} = 0.002$	$W_U = -6.453$ $p < 0.001$ $p_{BH} <0.001$	$W_U = -3.637$ $p < 0.001$ $p_{BH} < 0.001$	
LoD 2 + Color	$W_U = -2.440$ $p = 0.015$ $p_{BH} = 0.018$	$W_U = 0.544$ $p = 0.587$ $p_{BH} = 0.587$	$W_U = -3.480$ $p < 0.001$ $p_{BH} < 0.001$		
LoD 2 + Focus	$W_U = 0.935$ $p = 0.350$ $p_{BH} = 0.404$	$W_U = 4.095$ $p < 0.001$ $p_{BH} <0.001$			
LoD 2 + Texture	$W_U = -3.181$ $p = 0.001$ $p_{BH} = 0.002$				
First 4 Batches	$KW_H = 23.064$ $p < 0.001$				
First 4 Batches + Memory	$KW_H = 86.274$ $p < 0.001$				

KW_H : Kruskal-Wallis test; W_U: Wilcoxon rank-sum test; p: p-value;
p_{BH}: false discovery rate correction (Benjamin-Hochberg procedure)

Correctness score

The values depicted in this table are used in the sections 4.1.1. *Impact of the VGE representations on user performance* and 4.1.2. *Impact of the metaphors on user performance*.

	LoD 1 + Color	LoD 2 + Texture	LoD 2 + Focus	LoD 2 + Color	Memory
Static	$W_U = 2.772$ $p = 0.006$ $p_{BH} = 0.010+$	$W_U = 4.329$ $P < 0.001$ $p_{BH} < 0.001$	$W_U = 4.287$ $P < 0.001$ $p_{BH} < 0.001$	$W_U = 3.930$ $P < 0.001$ $p_{BH} < 0.001$	$W_U = -1.748$ $p = 0.081$ $p_{BH} = 0.110$
Memory	$W_U = 4.388$ $P < 0.001$ $p_{BH} < 0.001$	$W_U = 5.610$ $p < 0.001$ $p_{BH} < 0.001$	$W_U = 5.613$ $p < 0.001$ $p_{BH} < 0.001$	$W_U = 5.283$ $p < 0.001$ $p_{BH} < 0.001$	
LoD 2 + Color	$W_U = -1.492$ $p = 0.136$ $p_{BH} = 0.170$	$W_U = 0.472$ $p = 0.637$ $p_{BH} = 0.735$	$W_U = 0.0340$ $p = 0.734$ $p_{BH} = 0.787$		
LoD 2 + Focus	$W_U = -1.867$ $p = 0.062$ $p_{BH} = 0.093$	$W_U = 0.141$ $p = 0.888$ $p_{BH} = 0.888$			
LoD 2 + Texture	$W_U = -1.974$ $p = 0.048$ $p_{BH} = 0.081$				
First 4 Batches	$KW_H = 14.789$ $p = 0.002$				
First 4 Batches + Memory	$KW_H = 110.544$ $p < 0.001$				

KW_H : Kruskal-Wallis test; W_U: Wilcoxon rank-sum test; p: p-value;
p_{BH}: False discovery rate correction (Benjamin-Hochberg procedure)

socio-demographic characteristics

The values depicted in this table are used in the sections 4.2.1. *Gender*, 4.2.2. *Age*, and 4.2.3. *Other parameters*.

	Inputs Count	Completion Time	Correctness Score
Gender	$W_U = 0.901$ $p = 0.367$	$W_U = 1.435$ $p = 0.151$	$W_U = 2.916$ $p = 0.004$
Age	$K\tau = 0.143$ $p = 0.040$	$K\tau = 0.194$ $p = 0.005$	$K\tau = -0.108$ $p = 0.122$
Education	$K\tau = -0.129$ $p = 0.109$	$K\tau = -0.137$ $p = 0.086$	$K\tau = -0.073$ $p = 0.369$
3D Consumption	$K\tau = -0.113$ $p = 0.138$	$K\tau = -0.240$ $p = 0.002$	$K\tau = 0.133$ $p = 0.083$
Water-Level-Problem	$W_U = 3.145$ $p = 0.002$	$W_U = 2.070$ $p = 0.038$	$W_U = 3.294$ $p < 0.001$

$K\tau$: Kendall rank correlation coefficient; W_U: Wilcoxon rank-sum test; p: p-value;

User preference vote

The values depicted in this table are used in the section 4.3. *User preferences in interacting with VGE representation*.

	Easiest (N=98)	Hardest (N=98)
None	*8 (8.2 %)*	*7 (7.1 %)*
LoD 2 + Color	*11 (11.2 %)*	*15 (15.3 %)*
LoD 2 + Focus	*37 (37.8 %)*	*18 (18.4 %)*
LoD 2 + Texture	*15 (15.3 %)*	*35 (35.7 %)*
LoD 1 + Color	*27 (27.5 %)*	*23 (23.5 %)*

Bibliography

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Abelson, J., & Gauvin, F.-P. (2006). *Assessing the Impacts of Public Participation: Concepts, Evidence and Policy Implications* (No. 06; Public Involvement Network). https://ipea.gov.br/participacao/images/pdfs/participacao/abelson_julia_gauvin_francois_assessing_impacts_public_participation.pdf

Afzalan, N., & Muller, B. (2018). Online participatory technologies: Opportunities and challenges for enriching participatory planning. *Journal of the American Planning Association. American Planning Association*, *84*(2), 162–177.

Afzalan, N., Sanchez, T. W., & Evans-Cowley, J. (2017). Creating smarter cities: Considerations for selecting online participatory tools. *Cities*, *67*, 21–30.

Ahmed, F. C., & Sekar, S. P. (2015). Using three-dimensional volumetric analysis in everyday urban planning processes. *Applied Spatial Analysis and Policy*, *8*(4), 393–408.

Akbar, A., Flacke, J., Martinez, J., & van Maarseveen, M. F. A. M. (2020). Spatial Knowledge: A Potential to Enhance Public Participation? *Sustainability*, *12*(12), 5025.

Alatalo, T., Pouke, M., Koskela, T., Hurskainen, T., Florea, C., & Ojala, T. (2017). Two real-world case studies on 3D web applications for participatory urban planning. *Proceedings of the 22nd International Conference on 3D Web Technology - Web3D '17*.

Alawadi, K., & Dooling, S. (2016). Challenges and opportunities for participatory planning approaches within Dubai's urban context. *Journal of Urbanism: International Research on Placemaking and Urban Sustainability*, *9*(3), 276–301.

Al-Douri, F. (2017). Computational and Modeling Tools - How effectively are Urban Designers and Planners using them Across the Design Development Process? *Proceedings of the 35th International Conference on Education and Research in Computer Aided Architectural Design in Europe (eCAADe) [Volume 1]*.

Alexander, C., Ishikawa, S., & Silverstein, M. (1977). *A Pattern Language: Towns, Buildings, Construction*. Oxford University Press.

Al-Kodmany, K. (1999). Using visualization techniques for enhancing public participation in planning and design: process, implementation, and evaluation. *Landscape and Urban Planning*, *45*(1), 37–45.

Al-Kodmany, K. (2001). Visualization Tools and Methods for Participatory Planning and Design. *Journal of Urban Technology*, *8*(2), 1–37.

Al-Kodmany, K. (2002). Visualization tools and methods in community planning: From freehand sketches to virtual reality. *Journal of Planning Literature*, *17*(2), 189–211.

Appleton, K., & Lovett, A. (2003). GIS-based visualisation of rural landscapes: defining “sufficient” realism for environmental decision-making. *Landscape and Urban Planning*, *65*(3), 117–131.

Arab, N. (2007). Activité de projet et aménagement urbain : les sciences de gestion à l’épreuve de l'urbanisme. *Management & Avenir*, *12*(2), 147.

Arab, N., & Vivant, E. (2018). L’innovation de méthodes en urbanisme : freins et leviers d’une entreprise incertaine. *Cahiers de La Recherche Architecturale Urbaine et Paysagère*, *1*.

Arnstein, S. R. (1969). A Ladder of Citizen Participation. *Journal of the American Planning Association*, *35*(4), 216–224.

Aubert, A. H., Esculier, F., & Lienert, J. (2020). Recommendations for online elicitation of swing weights from citizens in environmental decision-making. *Operations Research Perspectives*, *7*, 100156.

Babelon, I., Pánek, J., Falco, E., Kleinhans, R., & Charlton, J. (2021). Between Consultation and Collaboration: Self-Reported Objectives for 25 Web-Based Geoparticipation Projects in Urban Planning. *ISPRS International Journal of Geo-Information*, *10*(11), 783.

Baeckelandt, S. (2020). *L’impératif délibératif, une reconfiguration des modalités de négociation entre pouvoir et société civile organisée ?*

Baker, M., Coaffee, J., & Sherriff, G. (2007). Achieving successful participation in the new UK spatial planning system. *Planning Practice and Research*, *22*(1), 79–93.

Balázs, B., Mooney, P., Nováková, E., Bastin, L., & Jokar Arsanjani, J. (2021). Data Quality in Citizen Science. In *The Science of Citizen Science* (pp. 139–157). Springer International Publishing.

Barnes, M., Newman, J., Knops, A., & Sullivan, H. (2003). Constituting “the public” in public participation. *Public Administration*, *81*(2), 379–399.

Barranco, J., & Wisler, D. (1999). Validity and systematicity of newspaper data in event analysis. *European Sociological Review*, *15*(3), 301–322.

Basile, M., & Terrin, J.-J. (2010). Le projet IP City Une recherche sur la place des technologies de réalité mixte dans les représentations du projet urbain. *Flux*, *n° 78*(4), 58–67.

Batty, M. (1997). Virtual geography. *Futures*, *29*(4-5), 337–352.

Berg, A. C., Giest, S. N., Groeneveld, S. M., & Kraaij, W. (2020). Inclusivity in Online Platforms: Recruitment Strategies for Improving Participation of Diverse Sociodemographic Groups. *Public Administration Review*, *80*(6), 989–1000.

Besançon, L., Issartel, P., Ammi, M., & Isenberg, T. (2017). Mouse, Tactile, and Tangible Input for 3D Manipulation. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*. CHI '17: CHI Conference on Human Factors in Computing Systems, Denver Colorado USA.

Bethlehem, J. (2010). Selection bias in web surveys. *International Statistical Review = Revue Internationale de Statistique*, *78*(2), 161–188.

Biljecki, F., Ledoux, H., & Stoter, J. (2016). An improved LOD specification for 3D building models. *Computers, Environment and Urban Systems*, *59*, 25–37.

Biljecki, F., Ledoux, H., Stoter, J., & Zhao, J. (2014). Formalisation of the level of detail in 3D city modelling. *Computers, Environment and Urban Systems*, *48*, 1–15.

Biljecki, F., Stoter, J., Ledoux, H., Zlatanova, S., & Çöltekin, A. (2015). Applications of 3D City Models: State of the Art Review. *ISPRS International Journal of Geo-Information*, *4*(4), 2842–2889.

BIMForum. (2013). *LEVEL OF DEVELOPMENT SPECIFICATION* (2nd). https://bimforum.org/wp-content/uploads/2022/02/BIMForum_LOD_2013_reprint.pdf

Blatrix, C. (2009). La démocratie participative en représentation. *Sociétés contemporaines*, *74*(2), 97.

Blondiaux, L., & Sintomer, Y. (2002). L'impératif délibératif. *Politix*, *15*(57), 17–35.

Boér, A., Cöltekin, A., & Clarke, K. C. (2013). An evaluation of web-based geovisualizations for different levels of abstraction and realism – what do users predict? *Proceedings of the 26th International Cartographic Conference*. 26th International Cartographic Conference, Dresden, Germany.

Bohøj, M., Borchorst, N. G., Bødker, S., Korn, M., & Zander, P.-O. (2011). Public deliberation in municipal planning. *Proceedings of the 5th International Conference on Communities and Technologies - C&T '11*.

Bouzguenda, I., Alalouch, C., & Fava, N. (2020). Examining digital participatory planning: Maturity assessment in a Small Dutch city. *Journal of Cleaner Production*, *264*, 121706.

Bouzguenda, I., Fava, N., & Alalouch, C. (2021). Would 3D digital participatory planning improve social sustainability in smart cities? An empirical evaluation study in less-advantaged areas. *Journal of Urban Technology*, 1–31.

Bowman, D. A., Koller, D., & Hodges, L. F. (1997). Travel in immersive virtual environments: an evaluation of viewpoint motion control techniques. *Proceedings of IEEE 1997 Annual International Symposium on Virtual Reality*, 45–52.

Brabham, D. C., & Guth, K. L. (2017). The deliberative politics of the consultative layer: Participation hopes and communication as design values of civic tech founders. *The Journal of Communication*, *67*(4), 445–475.

Brasebin, M., Christophe, S., Jacquinod, F., Vinesse, A., & Mahon, H. (2016). 3d geovisualization & stylization to manage comprehensive and participative local urban plans. *ISPRS Annals of Photogrammetry Remote Sensing and Spatial Information Sciences*, *IV-2/W1*, 83–91.

Brody, S. D., Godschalk, D. R., & Burby, R. J. (2003). Mandating citizen participation in plan making: Six strategic planning choices. *Journal of the American Planning Association. American Planning Association*, *69*(3), 245–264.

Brovelli, M. A., Minghini, M., & Zamboni, G. (2016). Public participation in GIS via mobile applications. *ISPRS Journal of Photogrammetry and Remote Sensing: Official Publication of the International Society for Photogrammetry and Remote Sensing* , *114*, 306–315.

Brown, G. (2012). Public Participation GIS (PPGIS) for regional and environmental planning: reflections on a decade of empirical research. *URISA Journal*, *24*(2), 7–19.

Brown, G. (2015). Engaging the wisdom of crowds and public judgement for land use planning using public participation geographic information systems. *Australian Planner*, *52*(3), 199–209.

Brown, G., Donovan, S., Pullar, D., Pocewicz, A., Toohey, R., & Ballesteros-Lopez, R. (2014). An empirical evaluation of workshop versus survey PPGIS methods. *Applied Geography* , *48*, 42–51.

Brown, G., & Eckold, H. (2020). An evaluation of public participation information for land use decisions: public comment, surveys, and participatory mapping. *Local Environment*, *25*(2), 85–100.

Brown, G., & Kyttä, M. (2018). Key issues and priorities in participatory mapping: Toward integration or increased specialization? *Applied Geography* , *95*, 1–8.

Brown, G., Reed, P., & Raymond, C. M. (2020). Mapping place values: 10 lessons from two decades of public participation GIS empirical research. *Applied Geography* , *116*(102156), 102156.

Bryson, J. M. (2004). What to do when Stakeholders matter. *Public Management Review*, *6*(1), 21–53.

Bryson, J. M., Quick, K. S., Slotterback, C. S., & Crosby, B. C. (2013). Designing Public Participation Processes. *Public Administration Review*, *73*(1), 23–34.

Bugs, G., Granell, C., Fonts, O., Huerta, J., & Painho, M. (2010). An assessment of Public Participation GIS and Web 2.0 technologies in urban planning practice in Canela, Brazil. *Cities*, *27*(3), 172–181.

Bugs, G., & Kyttä, M. (2019). Public Perception Spatial Data From the PPGIS Jaguarão Experiment. *Civic Engagement and Politics*, 177–198.

Burigat, S., & Chittaro, L. (2007). Navigation in 3D virtual environments: Effects of user experience and location-pointing navigation aids. *International Journal of Human-Computer Studies*, *65*(11), 945–958.

Cardullo, P., & Kitchin, R. (2019). Being a “citizen” in the smart city: up and down the scaffold of smart citizen participation in Dublin, Ireland. *GeoJournal*, *84*(1), 1–13.

Cariello, A., Ferorelli, R., & Rotondo, F. (2021). Tactical urbanism in Italy: From grassroots to institutional tool—assessing value of public space experiments. *Sustainability: Science Practice and Policy*, *13*(20), 11482.

Carpini, M. X. D., Cook, F. L., & Jacobs, L. R. (2004). Public Deliberation, Discursive Participation, And Citizen Engagement: A Review Of The Empirical Literature. *Annual Review of Political Science*, *7*(1), 315–344.

Carvajal Bermúdez, J. C., & König, R. (2022). Can digital technologies for city-making engage its users to build parklets in Vienna? - Citizen participation in the context of the platform city. *Journal of Urbanism*, 1–27.

Chambers, R. (2006). Participatory mapping and geographic information systems: Whose map? Who is empowered and who disempowered? Who gains and who loses? *The Electronic Journal of Information Systems in Developing Countries*, *25*(1), 1–11.

Chapon, P.-M., Beuret, C., Bolomier, C., Choisy, P., & Zambernardi, S. (2010). Cartes mentales et représentations spatiales de résidants en MARPA : un outil d'aide à l'implantation de nouvelles structures d'hébergement ? *Norois*, *216*, 57–66.

Chassin, T., Cherqui, A., Ingensand, J., & Joerin, F. (2021). Impact of Digital and Non-Digital Urban Participatory Approaches on Public Access Conditions: An Evaluation Framework. In *ISPRS International Journal of Geo-Information* (Vol. 10, Issue 8, p. 563).

Chassin, T., & Ingensand, J. (2021). Are city features influencing the behavior of photographers? An analysis of Geo-referenced photos shooting orientation. *ISPRS - International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences*, *XLIII-B4-2021*, 353–359.

Chassin, T., Ingensand, J., Christophe, S., & Touya, G. (2022). Experiencing virtual geographic environment in urban 3D participatory e-planning: A user perspective. *Landscape and Urban Planning*, *224*(104432), 104432.

Chassin, T., Ingensand, J., & Joerin, F. (2018). *Towards the use of a 3D virtual globe to support public participatory decision making* (CONFERENCE). 12-15 June 2018.

Chassin, T., Ingensand, J., Lotfian, M., Ertz, O., & Joerin, F. (2019). Challenges in creating a 3D participatory platform for urban development. *Advances in Cartography and GIScience of the ICA*, *1*, 1–8.

Chassin, T., Ingensand, J., Touya, G., & Christophe, S. (2021). How do users interact with Virtual Geographic Environments? Users' behavior evaluation in urban participatory planning. *Proceedings of the ... IEEE International Conference on Acoustics, Speech, and Signal Processing / Sponsored by the Institute of Electrical and Electronics Engineers Signal Processing Society. ICASSP*, *4*, 1–8.

Chételat, J. (2005). *Éléments méthodologiques de diagnostic paysager utilisant les systèmes d'information géographique*. Lausanne, EPFL.

Chiaramonte, C. (2007). *Attraction de l'attention par des différences relatives de familiarité: étude expérimentale de la dynamique des processus précoces* (C. Marendaz (ed.)) [University Grenoble 2].

Chowdhury, S., & Schnabel, M. A. (2019). Laypeople's Collaborative Immersive Virtual Reality Design Discourse in Neighborhood Design. *Frontiers in Robotics and AI*, *6*, 97.

Chowdhury, S., & Schnabel, M. A. (2020). Virtual environments as medium for laypeople to communicate and collaborate in urban design. *Architectural Science Review*, *63*(5), 451–464.

Chrastil, E. R., & Warren, W. H. (2012). Active and passive contributions to spatial learning. *Psychonomic Bulletin & Review*, *19*(1), 1–23.

Christmann, G., Singh, A., Stollmann, J., & Bernhardt, C. (2020). Visual communication in urban design and planning: The impact of mediatisation(s) on the construction of urban futures. *Urban Planning*, *5*(2), 1–9.

Christophe, S. (2008). Creative Cartography based on Dialogue. *Proceedings of AutoCarto 2008*. AutoCarto 2008, Shepherdstown (WV), USA. https://cartogis.org/docs/proceedings/2008/christophe.pdf

Christophe, S. (2011). Creative colours specification based on knowledge (COLorLEGend system). *The Cartographic Journal*, *48*(2), 138–145.

Christophe, S. (2020). Geovisualization: Multidimensional exploration of the territory. *Proceedings of the 15th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications*. 11th International Conference on Information Visualization Theory and Applications, Valletta, Malta.

Civic Tech Field. (2019). *A timeline of civic tech tells a data-driven story of the field*. Civic Tech Field Guide. https://civictech.guide/a-timeline-of-civic-tech-tells-a-data-driven-story-of-the-field/

Cohen, J. (1989). Deliberation and Democratic Legitimacy. In A. Hamlin & P. Petit (Eds.), *The Good Policy: Normative Analysis of the state* (pp. 17–34). Basil Blackwell.

Colombo, D., Serino, S., Tuena, C., Pedroli, E., Dakanalis, A., Cipresso, P., & Riva, G. (2017). Egocentric and allocentric spatial reference frames in aging: A systematic review. *Neuroscience and Biobehavioral Reviews*, *80*, 605–621.

Çöltekin, A., Bleisch, S., Andrienko, G., & Dykes, J. (2017). Persistent challenges in geovisualization – a community perspective. *International Journal of Cartography*, *3*(sup1), 115–139.

Çöltekin, A., Francelet, R., Richter, K.-F., Thoresen, J., & Fabrikant, S. I. (2018). The effects of visual realism, spatial abilities, and competition on performance in map-based route learning in men. *Cartography and Geographic Information Science*, *45*(4), 339–353.

Çöltekin, A., Griffin, A. L., Slingsby, A., Robinson, A. C., Christophe, S., Rautenbach, V., Chen, M., Pettit, C., & Klippel, A. (2020). Geospatial Information Visualization and Extended Reality Displays. *Manual of Digital Earth*, 229–277.

Çöltekin, A., Lokka, I., & Zahner, M. (2016). On The Usability And Usefulness Of 3d (Geo)visualizations – A Focus On Virtual Reality Environments. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLI-B2*, 387–392.

Cooke, B., & Kothari, U. (2001). *Participation: The New Tyranny?* Zed Books.

Cooper, T. L., Bryer, T. A., & Meek, J. W. (2006). Citizen-Centered Collaborative Public Management. *Public Administration Review*, *66*(s1), 76–88.

Corburn, J. (2003). Bringing local knowledge into environmental decision making. *Journal of Planning Education and Research*, *22*(4), 420–433.

Cortner, H. J., & Shannon, M. A. (1993). Embedding Public Participation in Its Political Context. *Journal of Forestry*, *91*(7), 14–16.

Couclelis, H., Golledge, R. G., Gale, N., & Tobler, W. (1987). Exploring the anchor-point hypothesis of spatial cognition. *Journal of Environmental Psychology*, *7*(2), 99–122.

Courage, C. (2013). The global phenomenon of tactical urbanism as an indicator of new forms of citizenship. *Engage 32: Citizenship and Belonging*. https://www.academia.edu/4078236/The_global_phenomenon_of_tactical_urbanism_as_an_indicator_of_new_forms_of_citizenship

Czepkiewicz, M., Jankowski, P., & Zwoliński, Z. (2018). Geo-questionnaire: a spatially explicit method for eliciting public preferences, behavioural patterns, and local knowledge – an overview. In *Quaestiones Geographicae* (Vol. 37, Issue 3, pp. 177–190).

Dai, L., Han, Q., de Vries, B., & Wang, Y. (2022). Exploring key determinants of willingness to participate in EIA decision-making on urban infrastructure projects. *Sustainable Cities and Society*, *76*(103400), 103400.

Dambruch, J., & Krämer, M. (2014). Leveraging public participation in urban planning with 3D web technology. *Proceedings of the Nineteenth International ACM Conference on 3D Web Technologies - Web3D '14*.

Davidson, S. (1998). Spinning the wheel of empowerment. *Planning*, *1262*, 14–15.

Dawes, S. S. (2008). The evolution and continuing challenges of E-governance. *Public Administration Review*, *68*, S86–S102.

Dechézelles, S. (2015). *Au-delà du Nimby: Registres de justification et économie des mobilisations contre des projets de parcs éoliens. Études de cas audois et ariégeois*. Mobilisation Collective et Confrontations, François-Rabelais University, Tours, France. http://www.socio-energie2015.fr/?page_id=1816

Dechézelles, S., & Olive, M. (2016). Introduction: Lieux familiers, lieux disputés–dynamiques des mobilisations localisées. *Norois*, *238-239*, 7–21.

Dell, N., Vaidyanathan, V., Medhi, I., Cutrell, E., & Thies, W. (2012). Yours is better! *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. CHI '12: CHI Conference on Human Factors in Computing Systems, Austin Texas USA.

Deng, T., Zhang, K., & Shen, Z.-J. (max). (2021). A systematic review of a digital twin city: A new pattern of urban governance toward smart cities. *Journal of Management Science and Engineering*, *6*(2), 125–134.

Desouza, K. C., & Bhagwatwar, A. (2014). Technology-enabled participatory platforms for civic engagement: The case of U.s. cities. *Journal of Urban Technology*, *21*(4), 25–50.

Devaux, A., Hoarau, C., Brédif, M., & Christophe, S. (2018). 3D Urban Geovisualization: In Situ Augmented And Mixed Reality Experiments. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *IV-4*, 41–48.

Devine-Wright, P. (2005). Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy*, *8*(2), 125–139.

Diederichs, F., Niehaus, F., & Hees, L. (2020). Guerilla Evaluation of Truck HMI with VR. *Virtual, Augmented and Mixed Reality. Design and Interaction*, 3–17.

Dong, W., Yang, T., Liao, H., & Meng, L. (2020). How does map use differ in virtual reality and desktop-based environments? *International Journal of Digital Earth*, *13*(12), 1484–1503.

Dong, W., Zhan, Z., Liao, H., Meng, L., & Liu, J. (2020). Assessing similarities and differences between males and females in visual behaviors in spatial orientation tasks. *ISPRS International Journal of Geo-Information*, *9*(2), 115.

Downes, M., & Lange, E. (2015). What you see is not always what you get: A qualitative, comparative analysis of ex ante visualizations with ex post photography of landscape and architectural projects. *Landscape and Urban Planning*, *142*, 136–146.

Doyle, J. (2008). *Public Participation: Principles and Best Practices for British Columbia* (No. 11). Office of the Auditor General of British Columbia. https://www.bcauditor.com/sites/default/files/publications/2008/report11/report/public-participation-principles-and-best-practices-british-columbia.pdf

Dübel, S., & Schumann, H. (2017). Visualization of Features in 3D Terrain. *ISPRS International Journal of Geo-Information*, *6*(11), 357.

Dumont, M., Touya, G., & Duchêne, C. (2018). Alternative transitions between existing representations in multi-scale maps. *Proceedings of the ICA*, *1*, 1–4.

Earl, J., Martin, A., McCarthy, J. D., & Soule, S. A. (2004). The use of newspaper data in the study of collective action. *Annual Review of Sociology*, *30*(1), 65–80.

Eggers, W. D. (2007). *Government 2.0: Using Technology to Improve Education, Cut Red Tape, Reduce Gridlock, and Enhance Democracy*. Rowman & Littlefield.

Eilola, S., & Fagerholm, N. (2021). *Online 3D-based participatory mapping for urban planning – pilot case shows usability challenges exist especially with smart phones*. University of Turku. https://sites.utu.fi/greenplace/online-3d-based-participatory-mapping-for-urban-planning-pilot-case-shows-usability-challenges-exist-especially-with-smart-phones/

Eilola, S., Jaalama, K., Kangassalo, P., Nummi, P., Staffans, A., & Fagerholm, N. (2021). *Review of 3D visualisations supporting communication in urban and landscape planning*. University of Turku, Finland. https://research.utu.fi/converis/portal/detail/Publication/62098342

Elmqvist, N., & Tsigas, P. (2008). A taxonomy of 3D occlusion management for visualization. *IEEE Transactions on Visualization and Computer Graphics*, *14*(5), 1095–1109.

Ertiö, T.-P. (2015). Participatory apps for urban planning—space for improvement. *Planning Practice and Research*, *30*(3), 303–321.

Evans-Cowley, J., & Hollander, J. (2010). The new generation of public participation: Internet-based participation tools. *Planning Practice and Research*, *25*(3), 397–408.

Evans, R., & Plows, A. (2007). Listening Without Prejudice? *Social Studies of Science*, *37*(6), 827–853.

Everatt, D., Marais, H., & Dube, N. (2010). Participation … for what purpose? Analysing the depth and quality of public participation in the integrated development planning process in Gauteng. *Politikon*, *37*(2-3), 223–249.

Fagerholm, N., Raymond, C. M., Olafsson, A. S., Brown, G., Rinne, T., Hasanzadeh, K., Broberg, A., & Kyttä, M. (2021). A methodological framework for analysis of participatory mapping data in research, planning, and management. *Geographical Information Systems*, *35*(9), 1848–1875.

Falco, E., & Kleinhans, R. (2018). Digital participatory platforms for co-production in urban development. *International journal of e-planning research*, *7*(3), 52–79.

Falco, E., Zambrano-Verratti, J., & Kleinhans, R. (2019). Web-based participatory mapping in informal settlements: The slums of Caracas, Venezuela. *Habitat International*, *94*(102038), 102038.

Faliu, B. (2019). *Un Environnement Virtuel Interactif et Immersif pour Faciliter la Créativité Collective des Citoyens dans les Projets de Design Urbain* (F. Merienne, A. Siarheyeva, & R. Lou (eds.)) [Arts et Métiers ParisTech].

Faliu, B., Siarheyeva, A., Lou, R., & Merienne, F. (2019). Design and Prototyping of an Interactive Virtual Environment to Foster Citizen Participation and Creativity in Urban Design. *Lecture Notes in Information Systems and Organisation*, 55–78.

Fechner, T., & Kray, C. (2014). Georeferenced Open Data and Augmented Interactive Geo-Visualizations as Catalysts for Citizen Engagement. *JeDEM - eJournal of eDemocracy and Open Government*, *6*(1), 14–35.

Foltête, J.-C., Ingensand, J., & Blanc, N. (2020). Coupling crowd-sourced imagery and visibility modelling to identify landscape preferences at the panorama level. *Landscape and Urban Planning*, *197*(103756), 103756.

Fortin, M.-J., & Fournis, Y. (2014). Dossier « Territoires en transition environnementale » – Vers une définition ascendante de l'acceptabilité sociale : les dynamiques territoriales face aux projets énergétiques au Québec. *Natures Sciences Sociétés*, *22*(3), 231–239.

Frank, K. I. (2006). The Potential of Youth Participation in Planning. *Journal of Planning Literature*, *20*(4), 351–371.

Frediani, A. A., & Boano, C. (2012). Processes for just products: The capability space of participatory design. In *The Capability Approach, Technology and Design* (pp. 203–222). Springer Netherlands.

Fung, A. (2006). Varieties of Participation in Complex Governance. *Public Administration Review*, *66*(s1), 66–75.

Fung, A. (2015). Putting the public back into governance: The challenges of citizen participation and its future. *Public Administration Review*, *75*(4), 513–522.

Gailing, L., & Leibenath, M. (2015). The social construction of landscapes: Two theoretical lenses and their empirical applications. *Landscape Research*, *40*(2), 123–138.

Gardony, A. L., Hendel, D. D., & Brunyé, T. T. (2022). Identifying optimal graphical level of detail to support orienting with 3D geo-visualizations. *Spatial Cognition and Computation*, *22*(1-2), 135–160.

Geertman, S. (2017). PSS: Beyond the implementation gap. *Transportation Research Part A: Policy and Practice*, *104*, 70–76.

Gill, L., & Lange, E. (2015). Getting virtual 3D landscapes out of the lab. *Computers, Environment and Urban Systems*, *54*, 356–362.

González, A., Gilmer, A., Foley, R., Sweeney, J., & Fry, J. (2008). Technology-aided participative methods in environmental assessment: An international perspective. *Computers, Environment and Urban Systems*, *32*(4), 303–316.

Goodchild, M. F. (2007). Citizens as sensors: the world of volunteered geography. *GeoJournal*, *69*(4), 211–221.

Gore, A. (1998). The Digital Earth. *Australian Surveyor*, *43*(2), 89–91.

Grêt-Regamey, A., Burlando, P., Girot, C., Lin, E. S., Shaad, K., & Vollmer, D. (2014). Digital Methods and Collaborative Platforms for Informing Design Values with Science. *Peer Reviewed Proceedings of Digital Landscape Architecture 2014*, 46–56.

Griffin, A. L., Coetzee, S., Kubicek, P., Camboim, S. P., Varanka, D. E., Harvey, F., Behr, F.-J., & Brus, J. (2021). Perspectives on making cartographic knowledge accessible to software developers. *Abstracts of the ICA*, *3*, 1–2.

Gün, A., Demir, Y., & Pak, B. (2020). Urban design empowerment through ICT-based platforms in Europe. *International Journal of Urban Sciences*, *24*(2), 189–215.

Haas Lyons, S. (2017). *Digital Engagement, Social Media & Public Participation*. International Association of Public Participation – IAP2 Canada. https://www.iap2canada.ca/resources/Documents/Newsletter/2017_social_media_white_paper.pdf

Hafferty, C., Berry, R., & Orford, S. (2022). *Web-based geospatial tools for stakeholder participation: Challenges and opportunities for planning and environmental governance*. 6th Conference Urban e-Planning , University of Lisbon, Portugal (online). https://drive.google.com/file/d/1eB7ezvDaHa4vg0_C67UC6oDneIzr6uVu/view?usp=embed_facebook

Haklay, M., Jankowski, P., & Zwoliński, Z. (2018). Selected modern methods and tools for public participation in urban planning – a review. *Quaestiones Geographicae*, *37*(3), 127–149.

Hamm, A., Shibuya, Y., Ullrich, S., & Cerratto Pargman, T. C. (2021). What makes civic tech initiatives to last over time? Dissecting two global cases. *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*. CHI '21: CHI Conference on Human Factors in Computing Systems, Yokohama Japan.

Handali, J. P., Schneider, J., Gau, M., Holzwarth, V., & vom Brocke, J. (2021). Visual Complexity and Scene Recognition: How Low Can You Go? *2021 IEEE Virtual Reality and 3D User Interfaces (VR)*.

Hart, R. A. (1992). *Children's Participation: From Tokenism to Citizenship*. UNICEF-IRC.

Harvey, F. (1997). Improving multi-purpose GIS design: Participative design. *Lecture Notes in Computer Science*, 313–328.

Harvey, M. (2009). Drama, Talk, and Emotion. *Science, Technology, & Human Values*, *34*(2), 139–161.

Hasler, S., Chenal, J., & Soutter, M. (2017). Digital Tools as a Means to Foster Inclusive, Data-informed Urban Planning. *Civil Engineering and Architecture*, *5*(6), 230–239.

Hausser, A., Lucas, J.-F., Devron, G., & Kaufmann, V. (2019). *Civic tech barometer 2019*. EPFL. https://www.epfl.ch/labs/lasur/civic-tech-barometer-2021/

Hayek, U. W. (2011). Which is the appropriate 3D visualization type for participatory landscape planning workshops? A portfolio of their effectiveness. *Environment and Planning. B, Planning & Design*, *38*(5), 921–939.

Hayek, U. W., Pieren, R., Heutschi, K., Manyoky, M., & Grêt-Regamey, A. (2017). Exploring the Qualities of Gis-Based Visual-Acoustic Simulations of Wind Parks to Support Public Opinion Forming. In *The Virtual and the Real in Planning and Urban Design* (1st Edition, pp. 233–251). Routledge.

Hayek, U. W., Wissen Hayek, U., von Wirth, T., Neuenschwander, N., & Grêt-Regamey, A. (2016). Organizing and facilitating Geodesign processes: Integrating tools into collaborative design processes for urban transformation. *Landscape and Urban Planning*, *156*, 59–70.

Healey, P. (1998). Collaborative planning in a stakeholder society. In *Town Planning Review* (Vol. 69, Issue 1, p. 1).

Heldal, I. (2007). Supporting participation in planning new roads by using virtual reality systems. *Virtual Reality*, *11*(2-3), 145–159.

Henn, M., & Foard, N. (2012). Young People, Political Participation and Trust in Britain. *Parliamentary Affairs*, *65*(1), 47–67.

Herbert, G., & Chen, X. (2015). A comparison of usefulness of 2D and 3D representations of urban planning. *Cartography and Geographic Information Science*, *42*(1), 22–32.

Herman, L., Juřík, V., Snopková, D., Chmelík, J., Ugwitz, P., Stachoň, Z., Šašinka, Č., & Řezník, T. (2021). A comparison of monoscopic and stereoscopic 3D visualizations: Effect on spatial planning in digital twins. *Remote Sensing*, *13*(15), 2976.

Herman, L., Juřík, V., Stachoň, Z., Vrbík, D., Russnák, J., & Řezník, T. (2018). Evaluation of user performance in interactive and static 3D maps. *ISPRS International Journal of Geo-Information*, *7*(11), 415.

Herman, L., Řezník, T., Stachoň, Z., & Russnák, J. (2018). The design and testing of 3DmoveR: An experimental tool for usability studies of interactive 3D maps. *Cartographic Perspectives*, *90*, 31–63.

Herman, L., & Stachoň, Z. (2016). Comparison of user performance with interactive and static 3d visualization – pilot study. *ISPRS - International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences*, *XLI-B2*, 655–661.

Hermann, L., Faltejsková, M., & Stachoň, Z. (2020). Comparison of Static Perspective Views and 2D Maps – the Role of Age, Spatial Abilities, and Task Nature. *(Teaching) Regional Geography. Proceedings of 27th Central European Conference. 17th October 2019, Brno*.

Hermans-van Ree, J. (2018). *The Rotterdam 3D City Model, from Innovation to Implementation*. 3D GeoInfo, Delft, Netherlands. https://d1rkab7tlqy5f1.cloudfront.net/BK/Over_de_faculteit/Afdelingen/OTB_-_Research_for_the_built_environment/Onderwijs/Presentaties%20OTB-studiedagen/2018/1.%20Jane%20van%20Ree%20181019_Rotterdam%203D%20city%20model.pdf

Hilbert, M., & López, P. (2011). The world's technological capacity to store, communicate, and compute information. *Science*, *332*(6025), 60–65.

Hoffmeyer-Zlotnik, J. H. P. (2016). *Standardisation and Harmonisation of Socio-Demographic Variables*. SDM-Survey Guidelines (GESIS Leibniz Institute for the Social Sciences).

Honey-Rosés, J. (2019). A review of field experiments in planning and urban research. *Planning Practice and Research*, *34*(5), 558–572.

Hopkins, D. (2010). The emancipatory limits of participation in planning: *Equity and power in deliberative plan-making in Perth, Western Australia*. *Town Planning Review*, *81*(1), 55–81.

Houghton, K., Miller, E., & Foth, M. (2014). Integrating ICT into the planning process: impacts, opportunities and challenges. *Australian Planner*, *51*(1), 24–33.

Hrivnák, M., Moritz, P., Melichová, K., Roháčiková, O., & Pospišová, L. (2021). Designing the Participation on Local Development Planning: From Literature Review to Adaptive Framework for Practice. *Societies*, *11*(1), 19.

Hunter, M., Soro, A., & Brown, R. (2021). Enhancing Urban Conversations for Smarter Cities: Augmented Reality as an enabler of digital civic participation. In *QUT ePrints* (No. 48).

Hu, Y., Lv, Z., Wu, J., Janowicz, K., Zhao, X., & Yu, B. (2015). A multistage collaborative 3D GIS to support public participation. *International Journal of Digital Earth*, *8*(3), 212–234.

IAP2. (2014). *Public Participation Spectrum* [Pdf]. International Association for Public Participation. https://iap2canada.ca/resources/Documents/IAP2%20Canada-Foundations-Spectrum_revised_june_orange.pdf

Ingensand, J., Lotfian, M., Ertz, O., Piot, D., Oberson, M., Oulevay, S., & Da Cunha, M. (2018). Augmented reality technologies for biodiversity education : *Proceedings of the 21st Conference on Geo-Information Science*, Article CONFERENCE. Agile 2018, Lund, Sweden.

Innes, J. E., & Booher, D. E. (2004). Reframing public participation: strategies for the 21st century. In *Planning Theory & Practice* (Vol. 5, Issue 4, pp. 419–436).

Irvin, R. A., & Stansbury, J. (2004). Citizen Participation in Decision Making: Is It Worth the Effort? *Public Administration Review*, *64*(1), 55–65.

Isaacs, J. P., Gilmour, D. J., Blackwood, D. J., & Falconer, R. E. (2011). Immersive and Non immersive 3D virtual cit:Decision support tool for urban sustainability. *Journal of Information Technology in Construction (ITcon)*, *16*(10), 151–162.

Jaalama, K., Fagerholm, N., Julin, A., Virtanen, J.-P., Maksimainen, M., & Hyyppä, H. (2021). Sense of presence and sense of place in perceiving a 3D geovisualization for communication in urban planning – Differences introduced by prior familiarity with the place. *Landscape and Urban Planning*, *207*(103996), 103996.

Jacquinod, F., & Bonaccorsi, J. (2019). Studying social uses of 3D geovisualizations: Lessons learned from action-research projects in the field of flood mitigation planning. *ISPRS International Journal of Geo-Information*, *8*(2), 84.

Jankowski, J., & Hachet, M. (2013). A Survey of Interaction Techniques for Interactive 3D Environments. *Eurographics 2013 - STAR*.

Jankowski, J., & Hachet, M. (2015). Advances in interaction with 3D environments: Advances in interaction with 3D environments. *Computer Graphics Forum: Journal of the European Association for Computer Graphics*, *34*(1), 152–190.

Jankowski, P., Czepkiewicz, M., Młodkowski, M., & Zwoliński, Z. (2016). Geo-questionnaire: A Method and Tool for Public Preference Elicitation in Land Use Planning. *Transactions in GIS*, *20*(6), 903–924.

Jho, W., & Song, K. J. (2015). Institutional and technological determinants of civil e-Participation: Solo or duet? *Government Information Quarterly*, *32*(4), 488–495.

Jiang, H., Geertman, S., & Witte, P. (2020). Avoiding the planning support system pitfalls? What smart governance can learn from the planning support system implementation gap. *Environment and Planning. B, Urban Analytics and City Science*, *47*(8), 1343–1360.

Jobert, A. (1998). L'aménagement en politique. Ou ce que le syndrome NIMBY nous dit de l'intérêt général. *Politix*, *11*(42), 67–92.

Joerin, F., Desthieux, G., Beuze, S. B., & Nembrini, A. (2009). Participatory diagnosis in urban planning: proposal for a learning process based on geographical information. *Journal of Environmental Management*, *90*(6), 2002–2011.

Johansson, T., Segerstedt, E., Olofsson, T., & Jakobsson, M. (2016). Revealing social values by 3D city visualization in city transformations. *Sustainability: Science Practice and Policy*, *8*(2), 195.

Jory, C. A., Shankar, R., Taylor, K., Martin, J., & Smee, C. (2014). At the touch of a button: collecting client feedback. *Learning Disability Practice*, *17*(3), 36–38.

Judge, S., & Harrie, L. (2020). Visualizing a possible future: Map guidelines for a 3D detailed development plan. *Journal of Geovisualization and Spatial Analysis*, *4*(1).

Juřík, V., Herman, L., Kubíček, P., Stachoň, Z., & Šašinka, Č. (2016). Cognitive Aspects Of Collaboration In 3d Virtual Environments. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLI-B2*, 663–670.

Juřík, V., Herman, L., Snopková, D., Galang, A. J., Stachoň, Z., Chmelík, J., Kubíček, P., & Šašinka, Č. (2020). The 3D hype: Evaluating the potential of real 3D visualization in geo-related applications. *PloS One*, *15*(5), e0233353.

Kahila-Tani, M., Kytta, M., & Geertman, S. (2019). Does mapping improve public participation? Exploring the pros and cons of using public participation GIS in urban planning practices. *Landscape and Urban Planning*, *186*, 45–55.

Keehner, M., Hegarty, M., Cohen, C., Khooshabeh, P., & Montello, D. R. (2008). Spatial reasoning with external visualizations: what matters is what you see, not whether you interact. *Cognitive Science*, *32*(7), 1099–1132.

Kenyon, S., Lyons, G., & Rafferty, J. (2002). Transport and social exclusion: investigating the possibility of promoting inclusion through virtual mobility. *Journal of Transport Geography*, *10*(3), 207–219.

Kessels, R. P. C., Meulenbroek, O., Fernández, G., & Olde Rikkert, M. G. M. (2010). Spatial working memory in aging and mild cognitive impairment: effects of task load and contextual cueing. *Neuropsychology, Development, and Cognition. Section B, Aging, Neuropsychology and Cognition*, *17*(5), 556–574.

Kettunen, P., Irvankoski, K., Krause, C. M., Sarjakoski, T., & Tiina Sarjakoski, L. (2012). Geospatial images in the acquisition of spatial knowledge for wayfinding. *Journal of Spatial Information Science*, *5*.

Keysers, J. (2015). *Digital Globe Review 2015*. Australia and New Zealand Cooperative Research Centre for Spatial Information. https://www.crcsi.com.au/assets/Uploads/Globe-review-paper-March-2015.pdf

Khan, Z., Ludlow, D., Loibl, W., & Soomro, K. (2014). ICT enabled participatory urban planning and policy development. *Transforming Government People Process and Policy*, *8*(2), 205–229.

Kibria, M. S., Zlatanova, S., Itard, L., & van Dorst, M. (2009). GeoVEs as Tools to Communicate in Urban Projects: Requirements for Functionality and Visualization. In *Lecture Notes in Geoinformation and Cartography* (pp. 379–395).

Kim, H.-Y. (2017). Statistical notes for clinical researchers: Chi-squared test and Fisher's exact test. *Restorative Dentistry & Endodontics*, *42*(2), 152–155.

Kingston, R. (2007). Public participation in local policy decision-making: The role of web-based mapping. *The Cartographic Journal*, *44*(2), 138–144.

Kingston, R., Carver, S., Evans, A., & Turton, I. (2000). Web-based public participation geographical information systems: an aid to local environmental decision-making. *Computers, Environment and Urban Systems*, *24*(2), 109–125.

Kitchenham, B. (2014). *Procedures for Performing Systematic Reviews*. Department of Computer Science, Keele University, UK. http://artemisa.unicauca.edu.co/~ecaldon/docs/spi/kitchenham_2004.pdf

Kitchin, R., Young, G. W., & Dawkins, O. (2021). Planning and 3D Spatial Media: Progress, Prospects, and the Knowledge and Experiences of Local Government Planners in Ireland. *Planning Theory & Practice*, *22*(3), 349–367.

Kiwan, A., Sheta, S., & Michel, M. (2021). Challenges and opportunities of applying digital public participation tools in urban development projects in Egypt. (Dept. A). *MEJ. Mansoura Engineering Journal*, *46*(2), 116–125.

Knight Foundation, & Rita Allen Foundation. (2017). *Scaling Civic Tech: Paths to a Sustainable Future*. https://knightfoundation.org/wp-content/uploads/2020/03/Scaling_Civic_Tech_final.pdf

Koláčný, A. (1969). Cartographic information—a fundamental concept and term in modern cartography. *The Cartographic Journal*, *6*(1), 47–49.

Koontz, T. M. (2014). Social learning in collaborative watershed planning: the importance of process control and efficacy. *Journal of Environmental Planning and Management*, *57*(10), 1572–1593.

Korn, M. (2013). *Situating Engagement: Ubiquitous Infrastructures for In-situ Civic Engagement* (S. Bødker (ed.)) [Aahus Universitet].

Krämer, M., & Gutbell, R. (2015). A case study on 3D geospatial applications in the web using state-of-the-art WebGL frameworks. *Proceedings of the 20th International Conference on 3D Web Technology*.

Kubíček, P., Šašinka, Č., Stachoň, Z., Herman, L., Juřík, V., Urbánek, T., & Chmelík, J. (2019). Identification of altitude profiles in 3D geovisualizations: the role of interaction and spatial abilities. *International Journal of Digital Earth*, *12*(2), 156–172.

La Due Lake, R., La Due Lake, R., & Huckfeldt, R. (1998). Social Capital, Social Networks, and Political Participation. *Political Psychology*, *19*(3), 567–584.

Lafrance, F., Daniel, S., & Dragićević, S. (2019). Multidimensional Web GIS Approach for Citizen Participation on Urban Evolution. In *ISPRS International Journal of Geo-Information* (Vol. 8, Issue 6, p. 253).

Lak, A., & Zarezadeh Kheibari, S. (2020). Towards a framework for facilitating the implementation of Tactical Urbanism Practices: Assessment Criteria in the Place-making Approach in Iran. *Geoforum; Journal of Physical, Human, and Regional Geosciences*, *115*, 54–66.

Lallemand, C., & Gronier, G. (2018). *Méthodes de design UX: 30 méthodes fondamentales pour concevoir des expériences optimales*. Editions Eyrolles.

Landry, M. (1995). A Note on the Concept of “Problem.” *Organization Studies*, *16*(2), 315–343.

Lange, E. (2001). The limits of realism: perceptions of virtual landscapes. *Landscape and Urban Planning*, *54*(1-4), 163–182.

Lange, E. (2011). 99 volumes later: We can visualise. Now what? *Landscape and Urban Planning*, *100*(4), 403–406.

Lawrence, R. L., & Deagen, D. A. (2001). Choosing Public Participation Methods for Natural Resources: A Context-Specific Guide. *Society & Natural Resources*, *14*(10), 857–872.

Leao, S., & Izadpahani, P. (2016). Factors Motivating Citizen Engagement in Mobile Sensing: Insights from a Survey of Non-Participants. *Journal of Urban Technology*, *23*(4), 85–103.

Lefebvre, H. (1970). *La révolution urbaine*. Gallimard.

Lember, V. (2018). The Increasing Role of Digital Technologies in Co-Production and Co-Creation. *Co-Production and Co-Creation*, 115–127.

Lember, V., Brandsen, T., & Tõnurist, P. (2019). The potential impacts of digital technologies on co-production and co-creation. *Public Management Review*, *21*(11), 1665–1686.

Leroux, E., & Pupion, P.-C. (2022). Smart territories and IoT adoption by local authorities: A question of trust, efficiency, and relationship with the citizen-user-taxpayer. *Technological Forecasting and Social Change*, *174*(121195), 121195.

Levesque, J.-F., Harris, M. F., & Russell, G. (2013). Patient-centred access to health care: conceptualising access at the interface of health systems and populations. *International Journal for Equity in Health*, *12*, 18.

Liao, H., Dong, W., Peng, C., & Liu, H. (2017). Exploring differences of visual attention in pedestrian navigation when using 2D maps and 3D geo-browsers. *Cartography and Geographic Information Science*, *44*(6), 474–490.

Linders, D. (2012). From e-government to we-government: Defining a typology for citizen coproduction in the age of social media. *Government Information Quarterly*, *29*(4), 446–454.

Lindquist, M. (2007). Visualization for Citizen Initiated Public Participation: A Case Study. *Open House International*, *32*(2), 17–25.

Ling, C., Hanna, K., & Dale, A. (2009). A template for integrated community sustainability planning. *Environmental Management*, *44*(2), 228–242.

Lin, H., Chen, M., Lu, G., Zhu, Q., Gong, J., You, X., Wen, Y., Xu, B., & Hu, M. (2013). Virtual geographic environments (VGEs): A new generation of geographic analysis tool. *Earth-Science Reviews*, *126*, 74–84.

Lin, H., & Gong, J. (2001). Exploring virtual geographic environments. *Annals of GIS*, *7*(1), 1–7.

Lin, H., Xu, B., Chen, Y., Jing, Q., & You, L. (2022). The virtual geographic environments: More than the digital twin of the physical geographical environments. In *New Thinking in GIScience* (pp. 17–28). Springer Nature Singapore.

Linn, M. C., & Petersen, A. C. (1985). Emergence and characterization of sex differences in spatial ability: A meta-analysis. *Child Development*, *56*(6), 1479.

Liu, W., Dugar, S., McCallum, I., Thapa, G., See, L., Khadka, P., Budhathoki, N., Brown, S., Mechler, R., Fritz, S., & Shakya, P. (2018). Integrated Participatory and Collaborative Risk Mapping for Enhancing Disaster Resilience. *ISPRS International Journal of Geo-Information*, *7*(2), 68.

Li, W., Feng, T., Timmermans, H. J. P., Li, Z., Zhang, M., & Li, B. (2020). Analysis of citizens' motivation and participation intention in urban planning. *Cities*, *106*, 102921.

Lokka, I. E., & Çöltekin, A. (2018). Evaluating Route Learning Performance Of Older And Younger Adults In Differently-designed Virtual Environments: A Task-differential Analysis. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLII-4*, 383–387.

Lokka, I. E., & Çöltekin, A. (2019). Toward optimizing the design of virtual environments for route learning: empirically assessing the effects of changing levels of realism on memory. *International Journal of Digital Earth*, *12*(2), 137–155.

Lokka, I. E., & Çöltekin, A. (2020). Perspective switch and spatial knowledge acquisition: effects of age, mental rotation ability and visuospatial memory capacity on route learning in virtual environments with different levels of realism. *Cartography and Geographic Information Science*, *47*(1), 14–27.

Lokka, I. E., Çöltekin, A., Wiener, J., Fabrikant, S. I., & Röcke, C. (2018). Virtual environments as memory training devices in navigational tasks for older adults. *Scientific Reports*, *8*(1), 10809.

Lotfian, M., Ingensand, J., & Brovelli, M. A. (2020). A Framework for Classifying Participant Motivation that Considers the Typology of Citizen Science Projects. *ISPRS International Journal of Geo-Information*, *9*(12), 704.

Lovett, A., Appleton, K., Warren-Kretzschmar, B., & Von Haaren, C. (2015). Using 3D visualization methods in landscape planning: An evaluation of options and practical issues. *Landscape and Urban Planning*, *142*, 85–94.

Luciano, E. M., Wiedenhöft, G. C., & dos Santos, F. P. (2018). Promoting social participation through digital governance. *Proceedings of the 19th Annual International Conference on Digital Government Research: Governance in the Data Age*.

Lydon, M., & Garcia, A. (2015). *Tactical Urbanism: Short-term Action for Long-term Change*. Island Press.

Lynch, K. (1960). *The Image of the City*. MIT Press.

MacEachren, A. M. (2001). Cartography and GIS: extending collaborative tools to support virtual teams. *Progress in Human Geography*, *25*(3), 431–444.

Macintosh, A. (2004). Characterizing e-participation in policy-making. *37th Annual Hawaii International Conference on System Sciences, 2004. Proceedings of the Conference on System Sciences*.

Mackinlay, J. D., Card, S. K., & Robertson, G. G. (1990). Rapid controlled movement through a virtual 3D workspace. *ACM SIGGRAPH Computer Graphics*, *24*(4), 171–176.

Manyoky, M., Hayek, U., Heutschi, K., Pieren, R., & Grkt-Regamey, A. (2015). Developing a GIS-Based Visual-Acoustic 3D Simulation for Wind Farm Assessment. *Wind Resources and Future Energy Security*, 69–96.

Martínez, M. (2011). The Citizen Participation of Urban Movements in Spatial Planning: A Comparison between Vigo and Porto. *International Journal of Urban and Regional Research*, *35*(1), 147–171.

Martin, H. (2016). *Maquette numérique 3D pour la construction : visualiser les connaissances métier et interagir avec des dispositifs immersifs* [Université Paris-Saclay].

Marzouki, A., Mellouli, S., & Daniel, S. (2017). Towards a Context-based Citizen Participation Approach. *Proceedings of the 10th International Conference on Theory and Practice of Electronic Governance - ICEGOV '17*.

Marzouki, A., Mellouli, S., & Daniel, S. (2019). A qualitative framework for data collection and analysis in Participation processes. *Proceedings of the 20th Annual International Conference on Digital Government Research*. dg.o 2019: 20th Annual International Conference on Digital Government Research, Dubai United Arab Emirates.

Marzouki, A., Mellouli, S., & Daniel, S. (2022). Understanding issues with stakeholders participation processes : A conceptual model of SPPs' dimensions of issues. *Government Information Quarterly*, *39*(2), 101668.

Matsuoka, R. H., & Kaplan, R. (2008). People needs in the urban landscape: Analysis of Landscape And Urban Planning contributions. *Landscape and Urban Planning*, *84*(1), 7–19.

Mattila, H., & Nummi, P. (2022). The challenge of the digital public sphere: Finnish experiences of the role of social media in participatory planning. *Planning Theory & Practice*, 1–17.

Mayer, R. E., & Moreno, R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist*, *38*(1), 43–52.

McCall, M. K., & Dunn, C. E. (2012). Geo-information tools for participatory spatial planning: Fulfilling the criteria for "good" governance? *Geoforum*, *43*(1), 81–94.

McCarthy, J. D., McPhail, C., & Smith, J. (1996). Images of Protest: Dimensions of Selection Bias in Media Coverage of Washington Demonstrations, 1982 and 1991. *American Sociological Review*, *61*(3), 478.

McCrae, J., Mordatch, I., Glueck, M., & Khan, A. (2009). Multiscale 3D navigation. *Proceedings of the 2009 Symposium on Interactive 3D Graphics and Games - I3D '09*.

McFee, B., Metsai, A., McVicar, M., Balke, S., Thomé, C., Raffel, C., Zalkow, F., Malek, A., Dana, Lee, K., Nieto, O., Ellis, D., Mason, J., Battenberg, E., Seyfarth, S., Yamamoto, R., viktorandreevichmorozov, Choi, K., Moore, J., … Kim, T. (2022). *librosa/librosa: 0.9.2*. Zenodo.

McLain, R. J., Banis, D., Todd, A., & Cerveny, L. K. (2017). Multiple methods of public engagement: Disaggregating socio-spatial data for environmental planning in western Washington, USA. *Journal of Environmental Management*, *204*(Pt 1), 61–74.

Mehrotra, A., Pejovic, V., Vermeulen, J., Hendley, R., & Musolesi, M. (2016). My phone and me. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*. CHI'16: CHI Conference on Human Factors in Computing Systems, San Jose California USA.

Mericskay, B. (2013). *Cartographie en ligne et planification participative: analyse des usages du géoweb et d'Internet dans le débat public à travers le cas de la Ville de Québec*.

Metze, T. (2020). Visualization in environmental policy and planning: a systematic review and research agenda. *Journal of Environmental Policy & Planning*, *22*(5), 745–760.

Midler, C. (1998). *L'auto qui n'existait pas: management des projets et transformation de l'entreprise*. Dunod.

Milgram, P., Takemura, H., Utsumi, A., & Kishino, F. (1995). Augmented reality: a class of displays on the reality-virtuality continuum. In H. Das (Ed.), *Telemanipulator and Telepresence Technologies*. SPIE.

Møller, M. S., & Olafsson, A. S. (2018). The Use of E-Tools to Engage Citizens in Urban Green Infrastructure Governance: Where Do We Stand and Where Are We Going? *Sustainability*, *10*(10), 3513.

Montello, D. R. (1993). Scale and multiple psychologies of space. *Lecture Notes in Computer Science*, 312–321.

Morgan-Daniel, J., Adkins, L. E., Tennant, M. R., Norton, H. F., Hough, C., Edwards, M. E., Daley, M., & Rethlefsen, M. L. (2021). Piloting a diversity, equity, and inclusion needs assessment to explore patron perceptions at a university health science library. *Hypothesis* , *33*(1).

Mossberger, K., & Tolbert, C. J. (2021). Digital citizenship and digital communities. *International Journal of E-Planning Research*, *10*(3), 19–34.

Mostert, E. (2003). The challenge of public participation. *Water Policy*, *5*(2), 179–197.

Moya, S., Grau, S., & Tost, D. (2014). *First-person locomotion in 3D virtual environments: A usability analysis*. Verlag der Technischen Universität Graz.

Müller, J. (2021). Evaluation Methods for Citizen Design Science Studies: How Do Planners and Citizens Obtain Relevant Information from Map-Based E-Participation Tools? *ISPRS International Journal of Geo-Information*, *10*(2), 48.

Münster, S., Georgi, C., Heijne, K., Klamert, K., Rainer Noennig, J., Pump, M., Stelzle, B., & van der Meer, H. (2017). How to involve inhabitants in urban design planning by using digital tools? An overview on a state of the art, key challenges and promising approaches. *Procedia Computer Science*, *112*, 2391–2405.

Nabatchi, T. (2010). Addressing the citizenship and democratic deficits: The potential of deliberative democracy for public administration. *American Review of Public Administration*, *40*(4), 376–399.

Naz, A., Kopper, R., McMahan, R. P., & Nadin, M. (2017). Emotional qualities of VR space. *2017 IEEE Virtual Reality (VR)*.

Neuenschwander, N., Wissen Hayek, U., & Grêt-Regamey, A. (2014). Integrating an urban green space typology into procedural 3D visualization for collaborative planning. *Computers, Environment and Urban Systems*, *48*, 99–110.

Newell, R., & Canessa, R. (2015). Seeing, Believing, and Feeling: The Relationship between Sense of Place and Geovisualization Research. *Spaces and Flows: An International Journal of Urban and ExtraUrban Studies*, *6*(4), 15–30.

Newell, R., & Canessa, R. (2018). From sense of place to visualization of place: examining people-place relationships for insight on developing geovisualizations. *Heliyon*, *4*(2), e00547.

Newell, R., McCarthy, N., Picketts, I., Davis, F., Hovem, G., & Navarrete, S. (2021). Communicating complexity: interactive model explorers and immersive visualizations as tools for local planning and community engagement. *Facets (Ottawa)*, *6*(1), 287–316.

Nielsen, J. (1994). *Guerrilla HCI: Article by Jakob Nielsen*. Nielsen Norman Group. https://www.nngroup.com/articles/guerrilla-hci/

Nummi, P. (2018). Crowdsourcing local knowledge with PPGIS and social media for urban planning to reveal intangible cultural heritage. *Urban Planning*, *3*(1), 100–115.

Obama, B. (2009). *Remarks of the President in Welcoming Senior Staff and Cabinet Secretaries to the White House*. Welcoming Senior Staff and Cabinet Secretaries to the White House, Eisenhower Executive Office Building, White House. https://obamawhitehouse.archives.gov/the-press-office/remarks-president-welcoming-senior-staff-and-cabinet-secretaries-white-house

OECD. (2004). *Promise and Problems of E-Democracy Challenges of Online Citizen Engagement: Challenges of Online Citizen Engagement*. OECD Publishing.

OECD Publishing. (2005). *OECD E-government studies E-government for better government: OECD e-government studies*. Organization for Economic Co-operation and Development (OECD).

Oliveira e Costa, S., Aaltonen, J., & Rusanen, M. (2018). Making the most of brownfield sites in the Baltic Sea Region: Baltic Urban Lab has identified new ways to improve planning processes through public-private-people partnerships – the 4P approach. *Nordregio Policy Brief*, *6*(6), 4.

Onitsuka, K., Ninomiya, K., & Hoshino, S. (2018). Potential of 3D visualization for collaborative rural landscape planning with remote participants. *Sustainability: Science Practice and Policy*, *10*(9), 3059.

Onyimbi, J., Koeva, M., & Flacke, J. (2018). Public participation using 3D web-based city models: Opportunities for E-participation in Kisumu, Kenya. *ISPRS International Journal of Geo-Information*, *7*(12), 454.

O'Reilly, T. (2007). What Is Web 2.0: Design Patterns and Business Models for the Next Generation of Software. *International Journal of Digital Economics*, *65*, 21.

Özdirlik, B., & Terrin, J.-J. (2015). *La conception en question: la place des usagers dans les processus de projet*. Nouvelles éditions de l'Aube.

Pánek, J. (2016). From mental maps to GeoParticipation. *The Cartographic Journal*, *53*(4), 300–307.

Pánek, J. (2018a). Emotional Maps: Participatory Crowdsourcing of Citizens´ Perceptions of Their Urban Environment. *Cartographic Perspectives*, *91*.

Pánek, J. (2018b). Participatory mapping in Community participation – case study of Jeseník, Czech Republic. *Quaestiones Geographicae*, *37*(3), 151–162.

Parush, A., Ahuvia, S., & Erev, I. (2007). Degradation in Spatial Knowledge Acquisition When Using Automatic Navigation Systems. *Spatial Information Theory*, 238–254.

Pedregal, B., Laconi, C., & del Moral, L. (2020). Promoting Environmental Justice through Integrated Mapping Approaches: The Map of Water Conflicts in Andalusia (Spain). *ISPRS International Journal of Geo-Information*, *9*(2), 130.

Penchansky, R., & Thomas, J. W. (1981). The concept of access: definition and relationship to consumer satisfaction. *Medical Care*, *19*(2), 127–140.

Peng, Z.-R. (2001). Internet GIS for public participation. *Environment and Planning. B, Planning & Design*, *28*(6), 889–905.

People Powered. (2022). *DIGITAL PARTICIPATION PLATFORM RATINGS*. https://drive.google.com/file/d/17LoyexX5JA7qQ0islgw9jVVGDJK5eve6/view?usp=embed_facebook

Piaget, J., & Inhelder, B. (1956). *The Child's Conception of Space*. Humanities Press International.

Pickering, T., & Minnery, J. (2012). Scale and Public Participation: Issues in Metropolitan Regional Planning. *Planning Practice and Research*, *27*(2), 249–262.

Piga, B. E. A., Chiarini, C., Vegetti, I., Boffi, M., Rainisio, N., Bonnet, A., Signorelli, V., Tourre, V., & Servières, M. (2016). Mapping Ambiances: a synopsis of theory and practices in an interdisciplinary perspective. *Ambiances, Tomorrow. Proceedings of 3rd International Congress on Ambiances. Septembre 2016, Volos, Greece*, *1*, 367–372.

Pokore, A. E. (2020). La ville intelligente et la question de la participation citoyenne dans les collectivités publiques. *Communication, Technologies et Développement*, *8*.

Poplin, A., Pereira, G. C., & Rocha, M. C. F. (2013). The Participatory Cube: A Framework for Analysis of Online Participation Platforms. *Lecture Notes in Geoinformation and Cartography*, 395–414.

Pouke, M., Ylipulli, J., Rantala, S., Alavesa, P., Alatalo, T., & Ojala, T. (2019). A Qualitative Study on the Effects of Real-World Stimuli and Place Familiarity on Presence. *2019 IEEE 5th Workshop on Everyday Virtual Reality (WEVR)*.

Pretty, J. N. (1995). Participatory learning for sustainable agriculture. *World Development*, *23*(8), 1247–1263.

Priego, C., Breuste, J., & Rojas, J. (2008). Perception and value of nature in urban landscapes: A comparative analysis of cities in Germany, Chile and Spain. *Landscape Online*, *7*, 1–22.

Punt, E. P., Geertman, S. C. M., Afrooz, A. E., Witte, P. A., & Pettit, C. J. (2020). Life is a scene and we are the actors: Assessing the usefulness of planning support theatres for smart city planning. *Computers, Environment and Urban Systems*, *82*, 101485.

Raaphorst, K., Duchhart, I., van der Knaap, W., Roeleveld, G., & van den Brink, A. (2017). The semiotics of landscape design communication: towards a critical visual research approach in landscape architecture. *Landscape Research*, *42*(1), 120–133.

Raaphorst, K., Roeleveld, G., Duchhart, I., Van der Knaap, W., & Van den Brink, A. (2018). Reading landscape design representations as an interplay of validity, readability and interactivity: a framework for visual content analysis. *Visual Communication*, *19*(2), 163–197.

Reed, M. S. (2008). Stakeholder participation for environmental management: A literature review. *Biological Conservation*, *141*(10), 2417–2431.

Reed, M. S., Graves, A., Dandy, N., Posthumus, H., Hubacek, K., Morris, J., Prell, C., Quinn, C. H., & Stringer, L. C. (2009). Who's in and why? A typology of stakeholder analysis methods for natural resource management. *Journal of Environmental Management*, *90*(5), 1933–1949.

Reed, M. S., Vella, S., Challies, E., de Vente, J., Frewer, L., Hohenwallner-Ries, D., Huber, T., Neumann, R. K., Oughton, E. A., del Ceno, J. S., & van Delden, H. (2018). A theory of participation: what makes stakeholder and public engagement in environmental management work? *Restoration Ecology*, *26*, S7–S17.

Regan, D. (1986). Form from motion parallax and form from luminance contrast: vernier discrimination. *Spatial Vision*, *1*(4), 305–318.

Reinart, B., & Poplin, A. (2014). Games in urban planning – a comparative study. *REAL CORP 2014 – PLAN IT SMART! Clever Solutions for Smart Cities. Proceedings of 19th International Conference on Urban Planning, Regional Development and Information Society*, 239–248.

Ring, K. (2020, June 1). *Introducing Cesium OSM Buildings*. Cesium. https://cesium.com/blog/2020/06/01/cesium-osm-buildings/

Rinner, C. (2001). Argumentation Maps: GIS-Based Discussion Support for On-Line Planning. In *Environment and Planning B: Planning and Design* (Vol. 28, Issue 6, pp. 847–863).

Roque de Oliveira, A., & Partidário, M. (2020). You see what I mean? – A review of visual tools for inclusive public participation in EIA decision-making processes. *Environmental Impact Assessment Review*, *83*(106413), 106413.

Rosener, J. B. (1978). Citizen Participation: Can We Measure Its Effectiveness? *Public Administration Review*, *38*(5), 457.

Roth, R. E. (2013). Interactive maps: What we know and what we need to know. *Journal of Spatial Information Science*, *6*.

Rowe, G., & Frewer, L. J. (2000). Public Participation Methods: A Framework for Evaluation. *Science, Technology, & Human Values*, *25*(1), 3–29.

Rowe, G., & Frewer, L. J. (2005). A typology of public engagement mechanisms. *Science, Technology & Human Values*, *30*(2), 251–290.

Ruming, K. (2018). Post-political planning and community opposition: asserting and challenging consensus in planning urban regeneration in Newcastle, New South Wales. In *Geographical Research* (Vol. 56, Issue 2, pp. 181–195).

Ruming, K., Houston, D., & Amati, M. (2012). Multiple Suburban Publics: Rethinking Community Opposition to Consolidation in Sydney. *Geographical Research*, *50*(4), 421–435.

Saad-Sulonen, J. (2012). The role of the creation and sharing of digital media content in participatory E-planning. *International journal of e-planning research*, *1*(2), 1–22.

Sabri, S., Rajabifard, A., Ho, S., Amirebrahimi, S., & Bishop, I. (2016). Leveraging VGI Integrated with 3D Spatial Technology to Support Urban Intensification in Melbourne, Australia. *Urban Planning*, *1*(2), 32–48.

Saebom Kwon, Mark Lindquist, Shannon Sylte, Gwen Gell, Awadhiya, {ayush, & Kidus Ayalneh Admassu. (2019). Land.Info: Interactive 3D Visualization for Public Space Design Ideation in Neighborhood Planning. *CHI EA '19: Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, 1–6.

Salak, B., Kienast, F., Olschewski, R., Spielhofer, R., Wissen Hayek, U., Grêt-Regamey, A., & Hunziker, M. (2022). Impact on the perceived landscape quality through renewable energy infrastructure. A discrete choice experiment in the context of the Swiss energy transition. *Renewable Energy*, *193*, 299–308.

Salter, J. D., Campbell, C., Journeay, M., & Sheppard, S. R. J. (2009). The digital workshop: exploring the use of interactive and immersive visualisation tools in participatory planning. *Journal of Environmental Management*, *90*(6), 2090–2101.

Santella, A., & DeCarlo, D. (2004). Visual interest and NPR. *Proceedings of the 3rd International Symposium on Non-Photorealistic Animation and Rendering - NPAR '04*. the 3rd international symposium, Annecy, France.

Santini, R. M., & Carvalho, H. (2019). The rise of participatory despotism: a systematic review of online platforms for political engagement. *Journal of Information Communication and Ethics in Society*, *17*(4), 422–437.

Saucier, C., Côté, G., Feurtey, É., Fortin, M.-J., Jean, B., Lafontaine, D., Guillemette, M., Méthot, J.-F., & Wilson, J. (2009). *Développement territorial et filière éolienne. Des installations éoliennes socialement acceptables : élaboration d'un modèle d'évaluation des projets dans une perspective de développement territorial durable*.

Saurman, E. (2016). Improving access: modifying Penchansky and Thomas's Theory of Access. *Journal of Health Services Research & Policy*, *21*(1), 36–39.

Schaik, P. Van. (2010). Interacting with Computers Using interactive 3-D visualization for public consultation. Interacting with Computers, pp. 556–568.

Scheerder, A., van Deursen, A., & van Dijk, J. (2017). Determinants of Internet skills, uses and outcomes. A systematic review of the second- and third-level digital divide. *Telematics and Informatics*, *34*(8), 1607–1624.

Schrock, A. R. (2019). What is civic tech? Defining a practice of technical pluralism. In *The Right to the Smart City* (pp. 125–133). Emerald Publishing Limited.

Schroth, O., Pond, E., Campbell, C., Cizek, P., Bohus, S., & Sheppard, S. R. J. (2011). Tool or toy? Virtual globes in landscape planning. *Future Internet*, *3*(4), 204–227.

Schüler, N., Agugiaro, G., Cajot, S., & Maréchal, F. (2018). Linking interactive optimization for urban planning with a semantic 3d city model. *ISPRS Annals of Photogrammetry Remote Sensing and Spatial Information Sciences*, *IV-4*, 179–186.

Sebastien, L. (2016). L'attachement au lieu, vecteur de mobilisation collective ? *Norois*, *238-239*, 23–41.

Seipel, S. (2013). Evaluating 2D and 3D geovisualisations for basic spatial assessment. *Behaviour & Information Technology*, *32*(8), 845–858.

Semmo, A., Trapp, M., Kyprianidis, J. E., & Döllner, J. (2012). Interactive visualization of generalized virtual 3D city models using level-of-abstraction transitions. *Computer Graphics Forum: Journal of the European Association for Computer Graphics*, *31*(3pt1), 885–894.

Sexton, K. (2013). Evolution of public participation in the assessment and management of environmental health risks: a brief history of developments in the United States. *Journal of Public Health Research*, *2*(2), e18.

Sheppard, S. R. J., & Cizek, P. (2009). The ethics of Google Earth: crossing thresholds from spatial data to landscape visualisation. *Journal of Environmental Management*, *90*(6), 2102–2117.

Sieber, R. (2006). Public Participation Geographic Information Systems: A Literature Review and Framework. *Annals of the Association of American Geographers*, *96*(3), 491–507.

Sieber, R., Robinson, P. J., Johnson, P. A., & Corbett, J. M. (2016). Doing Public Participation on the Geospatial Web. In *Annals of the American Association of Geographers* (Vol. 106, Issue 5, pp. 1030–1046).

Sifry, M. (2019). *Learning from the civic tech graveyard*. Civic Tech Field Guide. https://civictech.guide/learning-from-the-civic-tech-graveyard/

Silva, P. (2016). Tactical urbanism: Towards an evolutionary cities' approach? *Environment and Planning. B, Planning & Design*, *43*(6), 1040–1051.

Sinclair, A. J., Peirson-Smith, T. J., & Boerchers, M. (2017). Environmental assessments in the Internet age: the role of e-governance and social media in creating platforms for meaningful participation. *Impact Assessment and Project Appraisal*, *35*(2), 148–157.

Sintomer, Y. (2008). Du savoir d'usage au métier de citoyen ? *Raisons Politiques*, *31*(3), 115.

Skulmowski, A., & Rey, G. D. (2020). The realism paradox: Realism can act as a form of signaling despite being associated with cognitive load. *Human Behavior and Emerging Technologies*, *2*(3), 251–258.

Smallman, H. S., & John, M. S. (2005). Naive realism: Misplaced faith in realistic displays. *Ergonomics in Design: The Magazine of Human Factors Applications*, *13*(3), 6–13.

Smith, A., & Martín, P. P. (2021). Going beyond the smart city? Implementing technopolitical platforms for urban democracy in Madrid and Barcelona. *Journal of Urban Technology*, *28*(1-2), 311–330.

Smith, K., Berry, R., & Clarke, L. E. (2020). Exploring the potential of Google Earth as a communication and engagement tool in collaborative Natural Flood Management planning. *The Geographical Journal*, *186*(2), 171–185.

Stachoň, Z., Kubíček, P., Málek, F., Krejčí, M., & Herman, L. (2018). *The Role of Hue and Realism in Virtual Reality*.

Stanney, K. M., Mourant, R. R., & Kennedy, R. S. (1998). Human factors issues in virtual environments: A review of the literature. *Presence* , *7*(4), 327–351.

Star, S. L., & Griesemer, J. R. (1989). Institutional ecology, `translations' and boundary objects: Amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39. *Social Studies of Science*, *19*(3), 387–420.

StatCounter. (2022). *Desktop vs Mobile vs Tablet Market Share Worldwide*. StatCounter Global Stats. https://gs.statcounter.com/platform-market-share/desktop-mobile-tablet/worldwide/

Statista Research Department. (2022). *Global regional internet penetration rate 2022*. Statista. https://www.statista.com/statistics/269329/penetration-rate-of-the-internet-by-region/

Steiniger, S., Poorazizi, M. E., & Hunter, A. J. S. (2016). Planning with citizens: Implementation of an e-planning platform and analysis of research needs. *Urban Planning*, *1*(2), 46–64.

Stevens, Q., Awepuga, F., & Dovey, K. (2021). Temporary and tactical urbanism in Australia: Perspectives from practice. *Urban Policy and Research*, *39*(3), 262–275.

Subra, P. (2018). *Géopolitique de l'aménagement du territoire - 3e éd*. Armand Colin.

Surowiecki, J. (2004). *The Wisdom of Crowds: Why the Many are Smarter Than the Few and How Collective Wisdom Shapes Business, Economies, Societies, and Nations* (D. Books (ed.)). New York, NY, USA.

Swapan, M. S. H. (2016). Who participates and who doesn't? Adapting community participation model for developing countries. *Cities*, *53*, 70–77.

Talen, E. (1999). Constructing neighborhoods from the bottom up: the case for resident-enerated GIS. *Environment and Planning B: Planning and Design*, *26*(4), 533–554.

Talen, E. (2000). Bottom-up GIS. *Journal of the American Planning Association. American Planning Association*, *66*(3), 279–294.

Te Brommelstroet, M. (2010). Equip the warrior instead of manning the equipment: Land use and transport planning support in the Netherlands. *Journal of Transport and Land Use*, *3*(1).

Teyseyre, A. R., & Campo, M. R. (2009). An overview of 3D software visualization. *IEEE Transactions on Visualization and Computer Graphics*, *15*(1), 87–105.

Thöny, M., Schnürer, R., Sieber, R., Hurni, L., & Pajarola, R. (2018). Storytelling in interactive 3D geographic visualization systems. *ISPRS International Journal of Geo-Information*, *7*(3), 123.

Timney, M. M. (2011). Models of Citizen Participation: Measuring Engagement and Collaboration. In C. S. King (Ed.), *Government is us 2.0* (pp. 86–100). Routledge.

Tokarchuk, O., Cuel, R., & Zamarian, M. (2012). Analyzing crowd labor and designing incentives for humans in the loop. *IEEE Internet Computing*, *16*(5), 45–51.

Torre, A., & Beuret, J.-E. (2012). *Proximités territoriales: construire la gouvernance des territoires, entre conventions, conflits et concertations*. Economica.

Tutzauer, P., Becker, S., Niese, T., Deussen, O., & Fritsch, D. (2016). Understanding Human Perception of Building Categories in Virtual 3d Cities - a User Study. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLI-B2*, 683–687.

Tversky, A., & Kahneman, D. (1985). The Framing of Decisions and the Psychology of Choice. *Behavioral Decision Making*, 25–41.

Tversky, B. (2005). Functional Significance of Visuospatial Representations. *The Cambridge Handbook of Visuospatial Thinking*, 1–34.

Twitchen, C., & Adams, D. (2012). Using web technology to increase levels of public participation in planning. *The Town Planning Review*, *83*(6), vii – xiv.

Ugwitz, P., Juřík, V., Herman, L., Stachoň, Z., Kubíček, P., & Šašinka, Č. (2019). Spatial analysis of navigation in virtual geographic environments. *APPS. Applied Sciences*, *9*(9), 1873.

United Nations. (2014). *Revision of the World Urbanization Prospects* (Economic & Social Affairs). United Nations. http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf

United Nations, Department of Economic and Social Affairs, Population Division. (2018). *World Urbanization Prospects: The 2018 Revision* [Data set]. https://population.un.org/wup/DataQuery/

van der Land, S., Schouten, A. P., Feldberg, F., van den Hooff, B., & Huysman, M. (2013). Lost in space? Cognitive fit and cognitive load in 3D virtual environments. *Computers in Human Behavior*, *29*(3), 1054–1064.

van Deursen, A., & Mossberger, K. (2018). Any thing for anyone? A new digital divide in internet-of-things skills. *Policy & Internet*, *10*(2), 122–140.

van Deursen, A., & van Dijk, J. (2011). Internet skills and the digital divide. *New Media & Society*, *13*(6), 893–911.

van Dijk, J. A. G. M. (2017). Digital divide: Impact of access. In *The International Encyclopedia of Media Effects* (pp. 1–11). John Wiley & Sons, Inc.

van Krevelen, D. W. F., & Poelman, R. (2010). A Survey of Augmented Reality Technologies, Applications and Limitations. *International Journal of Virtual Reality*, *9*(2), 1–20.

van Leeuwen, J. P., Hermans, K., Jylhä, A., Quanjer, A. J., & Nijman, H. (2018). Effectiveness of virtual reality in participatory urban planning. *Proceedings of the 4th Media Architecture Biennale Conference*. MAB18: Media Architecture Biennale, Beijing China.

Vejre, H., Jensen, F. S., & Thorsen, B. J. (2010). Demonstrating the importance of intangible ecosystem services from peri-urban landscapes. *Ecological Complexity*, *7*(3), 338–348.

Velarde, J., Parejo, M., Blanco, J., & Moruno, L. (2017). Use of video and 3D scenario visualisation to rate vegetation screens for integrating buildings into the landscape. *Sustainability: Science Practice and Policy*, *9*(7), 1102.

Virtanen, J.-P., Hyyppä, H., Kurkela, M., Vaaja, M. T., Puustinen, T., Jaalama, K., Julin, A., Pouke, M., Kukko, A., Turppa, T., Zhu, L., Ojala, T., & Hyyppä, J. (2018). Browser based 3D for the built environment. In *Nordic Journal of Surveying and Real Estate Research* (Vol. 13, Issue 1, pp. 54–76).

Voinov, A., Çöltekin, A., Chen, M., & Beydoun, G. (2018). Virtual geographic environments in socio-environmental modeling: a fancy distraction or a key to communication? *International Journal of Digital Earth*, *11*(4), 408–419.

Voyer, D., Voyer, S., & Bryden, M. P. (1995). Magnitude of sex differences in spatial abilities: A meta-analysis and consideration of critical variables. *Psychological Bulletin*, *117*(2), 250–270.

Wagner, I., Broll, W., Jacucci, G., Kuutii, K., Mccall, R., Morrison, A., … Terrin, J.-J. (2009). On the Role of Presence in Mixed Reality. Presence, 18(4), 249–276.

Wanarat, K., & Nuanwan, T. (2013). Using 3D visualisation to improve public participation in sustainable planning process: Experiences through the creation of Koh mudsum plan, Thailand. *Procedia, Social and Behavioral Sciences*, *91*, 679–690.

Warren-Kretzschmar, B., & Tiedtke, S. (2005). What Role Does Visualization Play in Communication with Citizens? - A Field Study from the Interactive Landscape Plan. In H. Wichmann (Ed.), *Trends in Real-time Landscape Visualization and Participation: Proceedings at Anhalt University of Applied Sciences 2005* (pp. 156–167).

Wates, N. (2010). *The Community Planning Handbook: "How People Can Shape Their Cities, Towns and Villages in Any Part of the World."* Routledge.

Webler, T., Tuler, S., & Krueger, R. (2001). What is a good public participation process? Five perspectives from the public. *Environmental Management*, *27*(3), 435–450.

White, G., Zink, A., Codecá, L., & Clarke, S. (2021). A digital twin smart city for citizen feedback. *Cities* , *110*(103064), 103064.

White, S. C. (1996). Depoliticising development: The uses and abuses of participation. *Development in Practice*, *6*(1), 6–15.

Wilkening, J., & Fabrikant, S. I. (2013). How users interact with a 3D geo-browser under time pressure. *Cartography and Geographic Information Science*, *40*(1), 40–52.

Williamson, W., & Ruming, K. (2020). Can social media support large scale public participation in urban planning? The case of the #MySydney digital engagement campaign. *International Planning Studies*, *25*(4), 355–371.

Wilmer, H. H., Sherman, L. E., & Chein, J. M. (2017). Smartphones and Cognition: A Review of Research Exploring the Links between Mobile Technology Habits and Cognitive Functioning. *Frontiers in Psychology*, *8*, 605.

Wissen Hayek, U., & Grêt-Regamey, A. (2021). Conceptualizing a web-based 3d decision support system including urban underground space to increase urban resiliency. *Journal of Digital Landscape Architecture*, *6*, 85–93.

Wobbrock, J. O., Myers, B. A., & Aung, H. H. (2008). The performance of hand postures in front- and back-of-device interaction for mobile computing. *International Journal of Human-Computer Studies*, *66*(12), 857–875.

Wolbers, T., & Hegarty, M. (2010). What determines our navigational abilities? *Trends in Cognitive Sciences*, *14*(3), 138–146.

Wolfe, J. M., & Horowitz, T. S. (2004). What attributes guide the deployment of visual attention and how do they do it? *Nature Reviews Neuroscience*, *5*(6), 495–501.

Wright, L., & Davidson, S. (2020). How to tell the difference between a model and a digital twin. *Advanced Modeling and Simulation in Engineering Sciences*, *7*(1).

Wu, H., He, Z., & Gong, J. (2010). A virtual globe-based 3D visualization and interactive framework for public participation in urban planning processes. *Computers, Environment and Urban Systems*, *34*(4), 291–298.

Würstle, P., Santhanavanich, T., Padsala, R., & Coors, V. (2021). Development of a Digital 3d Participation Platform – Case Study of Weilimdorf (Stuttgart, Germany). *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLVI-4/W1-2021*, 123–129.

Wüstenhagen, R., Wolsink, M., & Bürer, M. J. (2007). Social acceptance of renewable energy innovation: An introduction to the concept. *Energy Policy*, *35*(5), 2683–2691.

Yeh, H. (2017). The effects of successful ICT-based smart city services: From citizens' perspectives. *Government Information Quarterly*, *34*(3), 556–565.

Yildiz, M. (2007). E-government research: Reviewing the literature, limitations, and ways forward. *Government Information Quarterly*, *24*(3), 646–665.

Yu, L., Zhang, X., He, F., Liu, Y., & Wang, D. (2020). Participatory rural spatial planning based on a virtual globe-based 3D PGIS. *ISPRS International Journal of Geo-Information*, *9*(12), 763.

Zaman, S. R., Sadekeen, D., Alfaz, M. A., & Shahriyar, R. (2021). One source to detect them all: Gender, age, and emotion detection from voice. *2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC)*. 2021 IEEE 45th Annual Computers, Software, and Applications Conference (COMPSAC), Madrid, Spain.

Zanola, S., Fabrikant, S. I., & Çöltekin, A. (2009). The Effect of Realism on the Confidence in Spatial Data Quality in Stereoscopic 3D Displays. *Proceedings, Proceedings, 24th International Cartography Conference (ICC 2009) (ICC 2009)*. Proceedings, 24th International Cartography Conference (ICC 2009), Santiago, Chile.

Zhang, A. (2017). *Speech Recognition* (Version Version 3.8) [Python]. https://github.com/Uberi/speech_recognition

Zhang, L., Geertman, S., Hooimeijer, P., & Lin, Y. (2019). The usefulness of a Web-based Participatory Planning Support System in Wuhan, China. *Computers, Environment and Urban Systems*, *74*, 208–217.

Zhang, S. (2019). Public participation in the Geoweb era: Defining a typology for geo-participation in local governments. *Cities*, *85*, 38–50.

Zhang, S., & Moore, A. B. (2014). The Usability of Online Geographic Virtual Reality for Urban Planning. *Lecture Notes in Geoinformation and Cartography*, 225–242.

Zhang, X. (2009). Multiscale traveling: crossing the boundary between space and scale. *Virtual Reality*, *13*(2), 101–115.

Zhang, Y. (2000). Using the Internet for Survey Research: A Case Study. *Journal of the American Society for Information Science*.

Zheng, M.-C., & Hsu, Y.-W. (2021). How 2.5D maps design improve the wayfinding performance and spatial ability of map users. *Informatics (MDPI)*, *8*(4), 88.

ZIMEYSAVER. (2017). ge.ch; Etat de Genève. https://www.ge.ch/node/3454

Žlender, V., Erjavec, I. Š., & Marušić, B. G. (2021). Digitally Supported Co-creation within Public Open Space Development Process: Experiences from the C3Places Project and Potential for Future Urban Practice. *Planning Practice & Research*, *36*(3), 247–267.

Zwass, V. (2010). Co-Creation: Toward a Taxonomy and an Integrated Research Perspective. *International Journal of Electronic Commerce*, *15*(1), 11–48.

THIBAUD CHASSIN

Participatory E-Planning Scientist & GIS Software Engineer

PROFILE

My background combines experience in industry and academia. I believe that these two cultures can be mutually enriching, therefore, I use my skills acquired over 7 years in order to accomplish my assigned tasks and cultivate my expertise, efficiently. Currently, I am finishing my Ph.D. that aims to investigate the use of 3D tools and methods in urban participatory e-planning. While doing my research, I work part-time as a teaching assistant.

CONTACT

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Switzerland

WORK EXPERIENCES

Oct 2022

GIS Teaching Assistant @ insit, HEIG-VD, Yverdon-les-Bains, 🇨🇭

Teaching: GIS (Bachelor 1st year), Supervising end year GIS projects (Bachelor 3rd year), and Development of advanced GIS tools (Master 1st year)
ArcGIS Pro, QGIS, Vue.JS, CesiumJS, Leaflet, Lecturing, Project Supervising, Problem solving, Adaptability

OGC Innovative Program: Contribution to Testbed-13: Vector Tiling and Testbed-14: Symbology Engineering Report
MapBox, Carto, International collaboration, Vector Tiling, Conceptual Thinking

Smapshot.heig-vd.ch: Pre-processing of large data sets of historical photos
Python, Large Data Set Processing

Oct 2017

Sept 2017

GIS Software Engineer @ Capgemini, Suresnes, 🇫🇷

SNCF: Project building and integration of an information system aiming railway data acquisition, management and sharing (Gaïa)
Powershell, Jira Api, Packaging & deployment automatization, PostgreSQL, Agile Methodology, Proactivity

French Postal Agency: Project development and operational maintenance of a GIS web application about mail delivery optimization
PHP, JavaScript (Bootstrap, Openlayers), Continuous Integration, Agile Methodology, Project Accountability

Veolia: Evolution and operational maintenance of a web GIS application about water supply network
Javascript, ArcGIS server & api, Microsoft IIS, FME, Python, Oracle, Agile Methodology, Proactivity

Feb 2016

Jan 2016

GIS Analyst @ LaSTIG, French Mapping Agency, St-Mandé, 🇫🇷

R&D: Use of a probabilistic method (RJMCMC) to optimize the label placement on maps. Java implementation of the process on Geoxygène (GIS platform developed by IGN - Cogit)
Java, SuperVisioN, Scientific Method

Sept 2015

Mar 2012

GIS Intern @ TotalEnergies, Pau, 🇫🇷

R&D: Total's Scientific Center campus – GIS 3D design and interior modeling
ESRI CityEngine, ArcMap, FME, Python, Procedural Modeling, Interoperability, Problem resolution

Aug 2012

Dec 2014

Intern @ Sorbonne University (formerly UPMC), Paris, 🇫🇷

Research: Which agricultural landscape model simulates the transfer of solid material outlet in a watershed?
Scientific writing, Bibliographical research

Jun 2014

THIBAUD CHASSIN

Participatory E-Planning Scientist &
GIS Software Engineer

LANGUAGES

French
Mother Tongue

English
Fluent

AWARDS

2019, **Computers & Geosciences Research Scholarships** co-sponsored by Elsevier and the International Association for Mathematical Geosciences (IAMG)

EDUCATION

Oct 2022

Ph.D. Candidate in 3D Participatory E-Planning @ LaSIG, EPFL, Lausanne, 🇨🇭

I design new approaches based on 3D (e.g. Virtual Geographic Environments) to better include citizens in urban participatory e-planning projects.

Oct 2017

2014

Master's Degree in Geomatic Sciences @ Sorbonne University (formerly UPMC), Paris, 🇫🇷

Algorithms based program, mobilized in several group projects from building a compiler (in C++) to a 3D GIS (based on Java 3D)

2012

2012

Bachelor's Degree in Geosciences & Environment @ Sorbonne University (formerly UPMC), Paris, 🇫🇷

2008

PUBLICATIONS

Peer-Reviewed Full Papers

(*in revision*) **Chassin, T.**, Ingensand: E-Guerrilla 3D Participation: Concept, Implementation and Usability Study, Frontiers in Virtual Reality

(*in revision*) **Chassin, T.**, Ingensand, F., Joerin: Media Coverage of 3D Visual Tools Used in Urban Participatory Planning, International Journal of E-Planning Research, **2022**.

Chassin, T., Ingensand, J., Touya, G., and Christophe, S.: Experiencing Virtual Geographic Environment in Urban 3D Participatory E-Planning: A User Perspective, Landscape and Urban Planning, 224(104432) doi: 10.1016/j.landurbplan.2022.104432, **2022**.

Chassin T., Cherqui A., Ingensand J., and Joerin F.: Impact of Digital and Non-Digital Urban Participatory Approaches on Public Access Conditions: An Evaluation Framework. ISPRS International Journal of Geo-Information; 10(8):563. doi: 10.3390/ijgi10080563, **2021**.

Chassin, T., Ingensand, J., Touya, G., and Christophe, S.: How do users interact with Virtual Geographic Environments? Users' behavior evaluation in urban participatory planning, Proc. Int. Cartogr. Assoc., 4, 19, doi: 10.5194/ica-proc-4-19-2021, **2021**.

Chassin, T., Ingensand, J., Lotfian, M., Ertz, O., and Joerin, F.: Challenges in creating a 3D participatory platform for urban development, Adv. Cartogr. GIScience Int. Cartogr. Assoc., 1, 3, doi: 10.5194/ica-adv-1-3-2019, **2019**.

THIBAUD CHASSIN

Participatory E-Planning Scientist &
GIS Software Engineer

HOBBIES

<u>One continent left to explore</u>
Oceania

<u>Sport</u>
Climbing (indoor & outdoor 7a)
Running (half-marathon 1h36)

<u>Entrepreneurship</u>
Attempted two projects on the Silver Economy

Currently working in my free time on a project related to the Doughnut Economy introduced by Kate Raworth

Administrative board member of Canolys, that brings innovation in coaching approaches

PUBLICATIONS

Abstract-Reviewed Full Papers, Abstracts, Short Papers

Chassin, T. and Ingensand, J.: Are city features influencing the behavior of photographers? An analysis of geo-referenced photos shooting orientation, Int. Arch. Photogramm. Remote Sens. Spatial Inf. Sci., XLIII-B4-2021, 353–359, doi: 10.5194/isprs-archives-XLIII-B4-2021-353-2021, **2021**.

Chassin, T., Lotfian, M., Ingensand, J., and Joerin, F.: A categorization of applied participatory 3d platforms in urban design, 5th International Conference Urban e-Planning, **2021**.

Chassin, T., Ingensand, J., Lotfian, M., Ertz, O., and Joerin, F.: Action-research: Assessment of using a 3D participatory platform for reviewing a Swiss city urban development plan, ECSA Conference, **2020**.

Lotfian, M., Ingensand, J., Ertz, O., Oulevay, S., and **Chassin, T.**: Auto-filtering validation in citizen science biodiversity monitoring: a case study, Proc. Int. Cartogr. Assoc., 2, 78, doi: 10.5194/ica-proc-2-78-2019, **2019**.

Ingensand, J., Nappez, M., Produit, T., and **Chassin, T.**: AUTOMATED RECONSTRUCTION OF 3D BUILDINGS IN HISTORIC CITY CENTERS FROM LIDAR DATA AND 2D BUILDING FOOTPRINTS, ISPRS Ann. Photogramm. Remote Sens. Spatial Inf. Sci., IV-4/W6, 19–23, doi: 10.5194/isprs-annals-IV-4-W6-19-2018, **2018**.

Chassin T., Ingensand J., and Joerin F., 2018. Towards the use of a 3D virtual globe to support public participatory decision making : short papers of the 21th AGILE Conference on Geographic Information Science. Lund University 12-15 June 2018, Lund, Sweden. ISBN 978-3-319-78208-9, **2018**.

Chassin T., Ingensand J., and Joerin F. Towards an open 3D participatory citizen debate. PeerJ Preprints 6:e27207v1 doi: 10.7287/peerj.preprints.27207v1, **2018**.

Touya, G. and **Chassin, T.**: RJMCMC based Text Placement to Optimize Label Placement and Quantity, Proc. Int. Cartogr. Assoc., 1, 116, doi: 10.5194/ica-proc-1-116-2018, **2018**.

THIBAUD CHASSIN

Participatory E-Planning Scientist &
GIS Software Engineer

TALKS

2022

6th International Conference Urban e-Planning @ Online 🌐

2021

XXIV ISPRS Congress - Interactive *poster* session @ Online 🌐

5th International Conference Urban e-Planning @ Online 🌐

International Cartographic Conference @ Florence 🇮🇹

(**Invited** talk) Webinar 3D et geospatial, 3D et e-participation dans l'aménagement du territoire @ Online 🌐

(**Invited** panelist) 3D technologies in public participation and urban green infrastructure planning, GAtES Project @ Online 🌐

2020

ECSA Conference - *Poster* session @ Online 🌐

2019

IEEE Consumer Communications & Networking Conference, 4th IEEE Workshop on Accessible Devices and Services (ADS) - Building a Crowdsourcing based Disabled Pedestrian Level of Service routing application using Computer Vision and Machine Learning, *Oral Presenter* @ Las Vegas, Nevada 🇺🇸

(**Invited** talk) Journée de formation continue geosuisse, 7e Veille technologique en géomatique - Création automatique et utilisation de bâtiments 3D pour l'aide à la décision @ Yverdon-les-Bains 🇨🇭

International Cartographic Conference @ Tokyo 🇯🇵

2018

21th AGILE Conference on Geographic Information Science, @ Lund 🇸🇪

5th Open Source Geospatial Research and Education (OGRS 2018) Symposium, @ Lugano 🇨🇭

(**Invited** talk) Journée Romande de la GeoInformation, Utilisation de maquettes 3D pour la participation @ Lausanne 🇨🇭

3D GeoInfo Conference @TU Delft 🇳🇱

2017

OGC Testbed Demonstrations Event, shared with the Vector Tiles Team @ Reston, Virginia 🇺🇸

NETWORKS

Personal page

LinkedIn
ResearchGate
GitHub
Google Scholar

ORCID:
0000-0003-1295-4373