Design and Prototyping of an Interactive Virtual Environment to Foster Citizen Participation and Creativity in Urban Design

Barnabé Faliu, Alena Siarheyeva, Ruding Lou, Frédéric Merienne

Abstract. Public Participation encounters great challenges in the domain of urban design concerning decision making and citizens' appropriation of a future place. Many tools and methods have been proposed to ease the participation process. In this paper we are targeting artefacts used in face-to-face workshops, in which citizens are asked to make design proposals for a public space. We claim that current state of the art can be improved (i) by better articulating digital artefacts with participatory processes and (ii) by providing interfaces that enhance citizen's spatial awareness and comprehension as well as collective creativity in urban design projects. We present the design and prototyping of an interactive virtual environment that follow the design-science research guidelines.

Keywords: ICT-enabled citizen participation ·co-creation ·urban design ·interactive virtual environment · design-science

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1 Introduction and Context

Public Participation (PP) has imposed in the last decades as one of the key factors of successful urban design and development projects. Lack of communication and collaboration between citizens and urban design experts can generate conflictual situations, leading to substantial delays and cost overheads, and eventually to project cancelation and political crisis as in Stuttgart 21, Notre-Dame-des-Landes or EuropaCity projects. To summarize:

> *"Design is not just for designers and their acolytes. Urban design, like all design, should involve a dialogue with the customer, whether the existing people within an area or those likely to move in." [59], (p. 11)*

The stakes of these projects are generally too critical to leave citizens voices apart. Urban designers and local authorities should not forget end users when designing public places in order to respect their quality of life and their 'ownership', in the sense of [35], whom define it as *"the right to act upon an issue…, a sense of belonging to a collective place" (p. 94).* Moreover, in most European countries, participatory processes are mandatory in urban projects aiming to modify the living environment of citizens, in line with the Aarhus Convention[1] and Council of Europe Recommendation 1430 (1999)[2]. As a result, a vast number of methodologies and toolkits have been developed lately, applicable to different steps of urban design and planning projects. Among these methodologies, an increasing number are focused on ICT-mediated PP in urban issues, which are: *"technology being addressed in such areas as governance, urban planning, information systems and interaction design, geography, citizen activism and community development"* [44] (p. 1). The ambition of an ICT tool for urban design is to provide a digital interface between experts and citizens to let them collaborate and benefit from each other's knowledge.

Urban design is a process that aims to define the shape of a city, district or public place and connect it to the surrounding environment (people or nature). It defines the spatial configuration and functionalities of a future urban area, but also considers civil society needs and financial aspects to define an attractive and sustainable area. The term urban design is different from urban planning, which is a long-term process focused on urban development, for instance land use plans, environment protection, infrastructures for transportation or job creation strategies. In other terms, urban planners diagnose macro-problems and urban designers manage to solve those problems.

Public authorities can decide to apply a certain degree of citizen involvement in the decision-making process. [55] divided the urban design process in four different steps: initiation, planning and design, implementation and maintenance. For each of these steps, citizens can be highly involved in the process and work in autonomy, or just be informed of the decisions without being consulted. The four different degrees of involvement are, from lowest to highest: information, consultation, collaboration and autonomy. This paper will be focused on design and prototyping of a digital artefact to enhance collaborative and creative design of non-trained participants. By non-trained we mean people not having particular skills in 3D design and/or urban design. More particularly, we consider face-to-face creative participatory sessions in which professionals and citizens work together to define the future of a public space such as a public park. We'll also pay attention to the definition of a process facilitating collaboration and co-creation of urban design proposals, and its articulation with the digital artefact.

The paper will be organized as follows. Section 2 will review existing literature and identify eventual gaps. Section 3 will present the research approach. Section 4 will present the main results: a process for collaborative and creative PP in urban design (4.1), specifications of a digital artefact rooted in field observations (4.2), and software architecture as well as user interfaces of a first prototype (4.3). Section 5 will discuss the results, highlight the contributions and acknowledges the limits of the current research, evaluate the research process with regards to design-science guidelines, and lay out directions for further investigations. Section 6 will conclude.

2 Literature Review

In the late 60's, S. Arnstein tackled the problem of citizen implication with her well-known ladder of citizen participation [9]. She edified the fact that most citizen participation processes are limited to information and consultation, where participants have less implication and impact upon the concerned project and are really close

[1] 1998 UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters, adopted by the fourth "Europe for Environment" conference in Aarhus, Denmark, on 25 June 1998.

[2] Council of Europe Recommendation 1430 (1999) of the Parliamentary Assembly on access to information, public participation in environmental decision-making and access to justice

to manipulation. In contrast, collaboration and autonomy provides a true level of citizen power. In the same time, the spirit of participatory planning, which is participatory design [52] applied to urban planning, emerged from the Scandinavian influence. The philosophy is to ensure a bottom-up approach to participation process by providing adequate methodologies and tools. Since then much work has been done on the subject, and participation methods can be various from focus groups to idea competitions and interactive displays in public spaces [55]. Our research is focused on a collaborative way of participation giving consequent decision power to citizen, in the form of iterative design workshops.

During the last decade, a large variety of methods and tools has been proposed to facilitate PP in urban design and planning [55]. Most of those tools traditionally rely on materials such as printed images, printed 2D maps, prepared 3D models, foam, pencils and paper. More recently, effort has been made to benefit from the advances in computer-aided tools to enhance citizen's interaction and engagement in the decision-making process [5]. We selected publications published between 2004 and 2018 that address the topic of a 3D artefact supporting PP in city making process.

Many research projects have demonstrated the value added of digital 3D environments for citizen participation [2–5, 23, 37, 56]. This new form of interaction helps participant to better understand the future of a place and support dialogue.

Based on the reviews presented by [13],[31] and [23], we can conclude that most of existing tools are focused on 3D visualization and feedback, which fall into information and consultation degree of participation according to [9]. That is, participants can only see professional proposals, give a feedback, or vote for a design proposal.

Few papers are eager to provide a higher degree of participation, namely collaboration and co-creation. In other words, efforts to define a digital artefact helping non-professional participants to express their ideas through the creation of urban design proposals can be increased. Such artefact shall also enhance collaboration between citizens and experts. A citizen-made design proposal shall be used to inspire urban design experts, so they can create comprehensive designs that take into account citizens opinions. As a result, such professional designs are more likely to be accepted.

The second observation of the reviews is that there is a divide between two main areas of research. Research led from Urban Studies standpoint generally defines PP processes and discusses eventual impacts of ICT-mediated participation, without implementing a digital artefact or considering eventual technological gaps [29–31, 44, 53, 54]. On another hand, research led in Information Systems or in Computer Science fields presents a digital artefact without taking into account its articulation around a participatory process, or without rigorous knowledge of the studied environment [12, 14, 49, 58, 60, 17, 20–22, 32, 38, 47, 48]. Furthermore, the above-mentioned contributions mainly propose solutions falling into the space of urban planning, not urban design.

A tentative to address either urban design processes and the artefact design is [39], which describes *"a new strategy of urban design with the purpose to overcome the technological perspective of current urban planning methods towards a participatory planning approach" (p. 187)*. However, the paper neither presents specifications and evaluation of the tool, nor its articulation with a participatory urban design process. The main function of the tool is to let users explore an urban design scenario, by changing position of 3D objects, or rotate them. Additionally, objects cannot be edited in terms of geometry, which limits creativity of participants. Moreover, this web tool is well adapted for massive participation but does not cover face-to-face workshop settings. The latter is usually facilitated in a manner to allow direct interaction, collaboration and co-creation between citizens and professionals and thus lead to more qualitative and comprehensive results. The analysis made by [23] confirms our diagnosis: *"The projects verify available technical possibilities and do not match real actions connected with social participation in planning […] Most of examples show how computer tools may be used for visualizing the new development and not for constructive process of continuous public participation" (p. 303).*

Research Problem

To address the identified gaps -lack of collaboration and co-creation tools, articulated around a well-defined participation process- we are eager to design and prototype a digital artefact to foster collaboration and collective creativity in participatory urban design projects. More particularly, we aim to bring Sander's concept of make tools for co-design [45] in the design process of our artefact. The artefact will be tailored to the settings of face-to-face workshops gathering professionals and non-professionals. Furthermore, it will be designed considering the essential rules and steps of a benchmarked participatory urban design process. Finally, we aim at using cutting-edge immersive and interactive interfaces for the prototype instantiation.

Our overall research question is the following:

How to integrate generative design concepts into an Interactive and Immersive Virtual Environment (IIVE) in order to enhance the creativity of participants to a collaborative workshop for public participation in urban design?

More specifically, we divide the question into 2 sub-questions as following:

RQ1: What are the specifications of an IIVE to foster citizen participation in urban design?
RQ2: What approach can be used for design and development of generative IIVE?

3 Research Approach

In order to bridge the approach from Urban Studies with that of Computer Science and Information Systems, while addressing the complexity of the Environment, design-science [26] seems to be an appropriate methodology. The research design and process along with presented results are expected to contribute to knowledge by theory testing and to practice with effective techniques to produce usable human computer systems in the context of PP in urban design.

3.1 Methodological Framework

In line with the guidelines of design-science research [26] to design, develop and evaluate the immersive collaborative digital artefact, we consider both the Environment of the research problem and its Knowledge Base. The study of the Environment, namely citizen participation in urban design, brings information about problems and needs of end-users and will help us to derive relevant functionalities afforded by virtual environment. To ensure research rigor, we build on the current state-of-the-art empirical contributions, available methodologies and place our research in a well-defined epistemological tradition. Figure 1 synthesizes the way our research is conducted. Environment analysis and Knowledge Base study feed the design, development and evaluation phase. Iterative development loops enable us to refine the digital artefact to bring it to the Environment. During the iterative design, development and assessment we are able to theorize the IT artifact [41] to further feed the Knowledge Base.

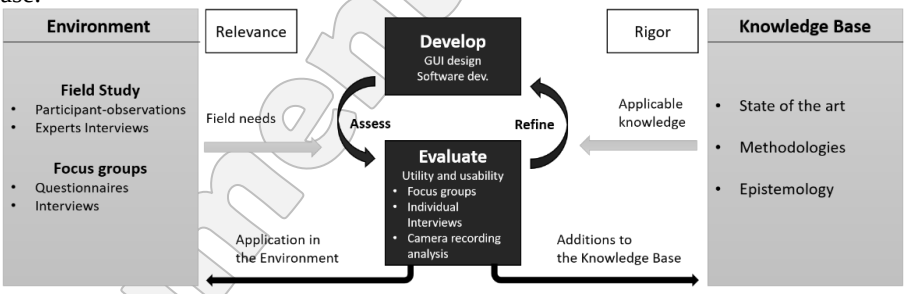

Fig. 1. Research approach overview inspired by design-science research [26]

Peffers et al. [42] described a process for carrying out design science research (DSR) in information systems consisting of six steps : problem identification and motivation, objective of a solution, design and development, demonstration, evaluation and communication. This process fits well with the Human-Computer Interaction (HCI) discipline focusing on design, evaluation and implementation of interactive systems, as explained S. Adikari [1].

3.2 Epistemological Position

Since the design of the digital artefact draws on study of humans within their social setting and on their experiences and interpretations, interpretivist epistemological stance and qualitative research seem to be well-suited for our research problem [7, 40]. According to the interpretivist tradition, any individual, researcher or an ordinary citizen, interprets the observed reality. Interpretations are conditioned by her/his life experience. For researcher, to know means to try to understand the ordinary sense that subjects assign to reality, considered as unknowable in its essence. To succeed in its mission of understanding the meaning given by subjects of the research, researcher should be capable of empathy. Understanding is situated at two levels: at the day-to-day life of the field investi-

gator and at the level of researcher who tries to derive meaning assigned by the subjects. Research is thus dependent on double subjectivity: that of the subjects of the research and that of the researcher. In contrast to positivism stipulating exteriority and neutrality vis-à-vis of the subject of the research, interpretivist researcher is engaged in her/his relation to the subjects of the research who transform themselves and retro-act on the researcher. Therefore, researcher has to take into account her/his position: she/he is part of the reality under investigation and cannot be outside of the interpretation process [34].

3.3 Environment

Our research project is informed with participant observation of a participatory design process of an urban park, as a part of a large urban renewal project in Marseille from April 2016 to March 2018. We adopted an ethnographic approach to discover the facilitation process and study in situ interactions between citizens and professionals during participatory workshops. We engaged in over participatory observation to become familiar with participants and the place and understand individual and collective issues at stake [18, 19]. In addition, we had an opportunity to run ethnographic observations of a participatory design of a sport and cultural community area near Marseille in March 2018. We combined the direct observations with in-depth semi-structured interviews of professional urban designers and planners to collect rich data. The ethnographic study of the participatory workshops offered an enriching empirical perspective that helps to understand the process of collective sense-making, creative expression and negotiation of the future of the place. It uncovers the role of facilitation methods that support these collective processes.

Last, to deepen our understanding of how participants engage with make tools [46] to express their ideas about the future of a place, we organized two simulations of participatory design workshops. The participation methodology employed was closed to the one we observed in Marseille and is described latter in this paper. We complemented our direct observations with semi-structured interviews with the participants of the simulations and analysis of video recordings.

3.4 Research Design

Our research design rests upon a variety of data sources including: (1) participant-observation of participatory urban design workshops; (2) interviews with professionals; (3) simulation of participatory workshops; (4) interviews of the participants of the simulations; (5) reports from the participatory workshops of the design of the public park in Marseille.

We started the investigations by attending the participatory workshops in Marseille. We were active at the workshops and interacted conversationally with various workshop participants: residents, activists, representatives of local associations, etc. We took photographs and notes during the participatory sessions. In a first phase, we interviewed the facilitator of the workshop, a person in charge of relations with citizens, and a professional urban designer managing the design of the park. We attended an alternative event focused on the future design of Marseille organized by city activists and interviewed the leader of the initiative. We triangulated this data with information about the urban renewal project of Marseille collected on Internet (press, blogs, social media).

In order to place the participatory design of the park in a broader professional practice context, we run semi-structured interviewed with two professional urban designers and a creative facilitation professional.

To obtain more information about collective creation practices and processes during participatory urban design workshops we conceived and run two simulations of co-creation workshops. The objective of the simulation was the same as that of the real workshops, envision together the future of a public space. The facilitation process borrowed the steps of the design of the park in Marseille, and an additional step was added asking participants to craft their own design proposal with make tools (see Figure 2). Each simulation workshop gathered 5-7 participants. They had diverse profiles: knowledge of urban design ranging from non-professional to professional level, knowledge of digital technologies ranging from beginners to skillful users, age ranging from 20 to 60 years old, half of them were female. We did not apply any kind of selection process. Building on the analysis of the simulation workshops, we defined a list of questions for semi-structured interviews of the participants and interviewed them.

The simulations were video recorded. The interviews were recorded and transcribed. Quotes have been translated from French to English for this paper.

This research design, combining observation of real participatory urban design workshops, simulations and interviews enabled us to gather rich data. A thematic content analysis of the collected qualitative data was conducted with NVivo software (version 10). Following the inductive qualitative method [6], we generated representative units and categories of analysis of the phenomenon from the environment data. We can thus shed light

on the collective negotiation and co-creation processes during participatory workshops. We can describe how boundary objects support these collective processes [46]; and derive requirements for design and development of the immersive interactive digital artefact.

We are convinced that this methodological approach, mixing the analysis of real case studies and simulated scenario workshops, with feedbacks from professionals of urban design, supplemented with our observations, is particularly suited to the research problem.

3.5 Design Process

Based on our research design, we derived the design of a digital artefact in a user-centered and iterative way. This methodology is commonly used in HCI and Interaction Design research projects. Iterative design is a process-based design research methodology in which designers create and test concepts in various basic forms prior to completing a full prototype (Fig. **2**). User-centered design is an iterative process that begins with stakeholder interviews and observational studies of activities prior to the typical design activity of brainstorming and generating ideas [43]. Interviews allow participants to talk about their experiences and provide more detailed, qualitative data, along with quantitative usability questionnaires. First, through observational studies, interviews and focus groups, we created knowledge in the form of personas, sketches and story-telling videos. Then, we made technological choices which we though were most adequate to the situation, in line with our interpretivist epistemological stance. Each material was used to define the requirements of an ICT tool and support an iterative software development process, linked with an evaluation process.

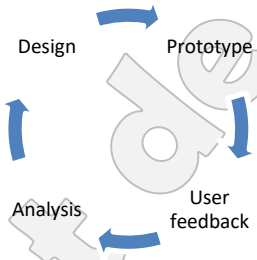

Fig. 2. User-centered design cycle

Software Development Process

The development-evaluation loop rests on the agile methodology spirit [11]. We currently implemented a first version of the prototype and plan to evaluate its utility and usability following the guidelines of [10]. Each future version of the prototype will consider user feedback (citizens, urban design professionals, immersive and interactive technologies professionals, etc.) gathered during the evaluation phase. In terms of organization, we followed Kanban methodology to follow up 3 different sub projects in a flexible manner [33], by translating requirement to user stories, tasks and sub tasks. Kanban allows the goal of a work in progress change during the development process, which is particularly convenient with our design process [36].

The benefits we see in the design-science approach are flexibility regarding the specification of the artefact, through repeated user tests, which result in the end in a user-defined software meeting the needs of the Environment; and a meaningful contribution to the Knowledge Base for future work in the form of a research design and process, combined with requirements of a digital artefact suited for our Environment.

Evaluation Process

To be in line with design-science research methodology and bring knowledge to IS field, we plan to run an evaluation of the designed artefact. We will focus the process on two points: usability and utility.

Usability evaluation will be a unipersonal evaluation made by different profile of users in terms of age, gender and ease with technology. We will gather quantitative data from following questionnaires : Immersive Tendencies Questionnaires & Presence Questionnaire [57], NASA TLX[24], QUESI [27] and an additional satisfaction questionnaire. Data will be completed with qualitative data through video analysis and coding as described by [8]. After each evaluation, feedbacks (bugs, additional feature, feature update, etc.) will be gathered and directly considered in the software development process.

To evaluate utility, we will organize four simulated workshops based on a real urban design project without any selection process. Participants will have to act as citizens and make a design proposal answering to few

requirements using the given artefact. Two workshops will be done with generative design concept integration, and two without. At the end of the process we will gather answers to the Creativity Support Index (CSI) [15, 16] in order to evaluate support to creativity for a particular task. We will collect qualitative data from video recording an ask open questions to participants at the end of the workshop. Finally, we will organize a vote about the four design proposals in terms of novelty (originality, uniqueness), resolution (logic, useful, valuable, understandable), elaboration and synthesis (the product is organic, well-crafted, and elegant) and see which configuration (with or without generative design concepts) supported best creativity of participants. This evaluation will be made by students from our university.

Evaluation of the artefact is an integral part of our research project but is not covered in the current paper due to space limitations.

4 Results

4.1 A Process for Collaborative and Creative PP in Urban Design

A Participatory Process to Support Collective Negotiation

Participant-observation of the early design phase of the urban park in Marseille enabled us to identify a generic sequence of participatory workshops to ensure citizen's expression, negotiation, consensus finding, and a convincing translation between expert's and citizen's language.

Fig. 3 illustrates the different stages starting from (1) the analysis of the current state of the place, followed by (2) an ideation session without spatial constraints, and finally (3a) refining of the previous step by spatially positioning the ideas. The results are used to feed professional work (4). Each step can be composed of several workshops and the global sequence can be repeated iteratively, as many times as needed.

For example, in the project under observation in Marseille there were two iterations, each composed of five workshops. The first iteration was to establish global specifications about the atmospheres and features of the park, along with the definition of separate zones. It resulted in the definition of requirements, and a competition to select an urban designer team proposing the most suited solution. The second iteration, involving the winning team of urban designers, was to define precisely the content of each zones and assess a final professional design proposal. The tools proposed to citizens during the different workshops were limited to 2D printed maps, printed images representing global features and atmospheres of public parks, pencils, post-its, scissors and printed questionnaire templates to give feedback.

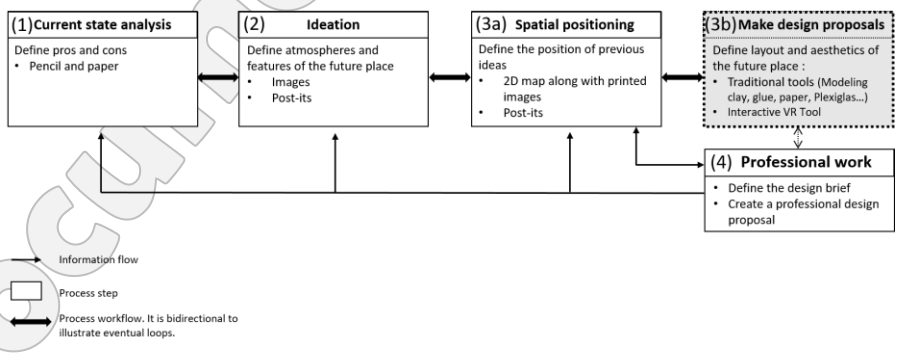

Fig. 3. Participation process inspired by the field observation. Dotted gray square highlights novelty from the observed process.

The analysis of the collective negotiation process has been constructed through several workshops observations and enables to derive an initial set of requirements for the definition of a digital artefact:

a) Reading of scales and distances must be easy
b) Possibility to define zone with associated surfacing, atmosphere, uses and street furniture
c) Transparency about technical, political and financial constraints
d) Precise definition of zones opened to collective negotiation, and zones not opened to public discussion due to technical, financial or other constraints
e) Necessity of a very rich library of visual representation of atmospheres, uses and street furniture, to unlock participants' imagination.

f) Expert's proposals should not be communicated too early not to lock participant's ideation
g) Expression of local knowledge (culture, uses of the place, heritage, history, …) needs to be facilitated

The participant-observation lead to the conclusion that creativity of participants can be further enhanced. The use of printed images certainly fed the expression of participants by means of various combinations of atmospheres and furniture. Nevertheless, current literature on co-creation highlights the need to improve the process by integrating the use of make tools [45].

Towards Creative Workspaces

Make tools support citizens' creativity by enabling them to express their latent and tacit level of experience, in addition to explicit and observable knowledge that can be expressed with words [45]. To access the explicit layer, well-known narration and visualization techniques are sufficient (the ones used in the observed urban design project). To access the tacit and latent level of knowledge, people should manipulate objects. This implies the integration of a new step (3b in **Fig. 3**) in the observed process with the help of make tools, focused on the creation of urban design proposals by citizen. Most used tools to achieve this step are 'pencil and paper' tools, meaning participants manipulate paper, scissors, glue, cardboards and pencils to represent elements such as a house, a fountain, basketball field, etc.

In order to identify additional requirements of the digital artefact and better understand how people express with make tools, we organized two simulated scenario workshops relying on traditional tools. The process embraced steps from (1) to (3b) in **Fig. 3** and the result of their work is visible in Fig. **4**.

By analyzing the camera/audio recording as well as the individual post-workshops interviews, we derived the following additional requirements:

h) Participants need a way to add contextual information in order to locate themselves and get a better understanding of the place
i) Participants need to have access to different types of materials/ground surfaces
j) Participants need to see reliefs on the map
k) Proposed prefabricated objects must be on scale
l) Participant need common objects to better understand spaces (a bus, a bench, a football field...)

We intend to support the presented process with the help of an interactive and immersive environment that will embrace requirements a) to l).

Fig. 4. A design proposal realized with traditional tools during one of the workshops we organized.

4.2 Specifications of a Virtual Environment for PP in Urban Design

In this section we define the specification of a digital artefact meeting the process and requirements presented above (Section 4.1). Based on field observations, we assume most users will have low skills in software manipulation and a good awareness of urban design constraints. Hence, using this artefact, a user (expert or amateur) shall be able to easily create a design proposal and associate information to it. Moreover, professionals need an

interface to extract useful information from citizen's ideas and implement professional design proposals. Therefore, we propose a conceptual framework composed of three parts, as shown in Fig. **5**: a creation workspace, a visualization and feedback workspace and a professional workspace.

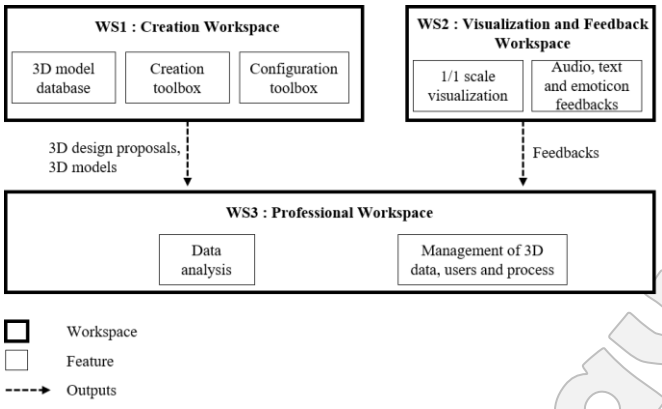

Fig. 5. Conceptual Framework of the Virtual Environment for PP in urban design

WS1: Creation Workspace

This workspace is the transposition in a virtual environment of a traditional creative workshop using prepared 3D models (basic shapes and city furniture), pencil and paper. Therefore, we propose to give users the opportunity to manipulate 3D models as freely as they would using scissors through a "cut and paste" metaphor.

We define the creation workspace as an interactive virtual environment where users can work in collaboration. This means that multiple users can interact with the interface concurrently, as they would do around a 2D map in currently observed configurations. The workspace is representing the future construction zone of the project with surrounding streets and infrastructures represented in 3D, with a predefined scale. To manipulate the environment, users are given multiple tools:

A categorized 3D model database. The categories may be straightforward as "houses" or "bridges" but also grouped by more abstract keywords as "Asian style garden" or "games for children".

A creation toolbox, which is the virtual representation of the manual actions used in standard creative workshops (hands manipulation to rotate, move, cut & assemble) and additional actions as 3D model scaling, cancel previous action, save current work.

A configuration toolbox allowing to add constraints and information to the workspace. For instance, define unmodifiable zones, associate metadata to objects or associate behaviors to preselected zones.

In other terms, this workspace can be seen as multiple layers with associated interactions. The first layer is a map with streets and infrastructure. The second layer gathers additional 3D models and constraints assigned to the first layer. The layer contains sematic information associated to the previous layers.

WS2: Visualization and Feedback Workspace

This is the place for immersive visualization and support of decision-making. The aim is to let the user explore its design proposal in a 1/1 scale, to fully understand the impact of his/her work and feel the atmosphere of the place. This workspace shall be used iteratively with the creation workspace to refine the design proposal. In this workspace, no modification of the current work is possible, the user can only explore the place and associate feedbacks or comments to specific zones.

WS3: Professional Workspace

This workspace allows professionals to visualize and analyze citizen's proposals and access feedbacks gathered during workshops. From this interface, they also have access to management features regarding 3D data, users and process. The aim is to help them in decision-making and inspire their future work.

Articulation with Participation Process

Finally, we synthetize our design process by introducing an articulation of the extended participation process with the conceptual framework (Fig. **6**). For each steps of the participation process, a workspace is related. Steps

(1) and (2) are supported by the visualization workspace to provide citizens material for inspiration and to initiate debates. Steps (3a) and (3b) is where true collaboration will occur, when citizens become designers of their district. To do so, they will need both the visualization workspace and the creation workspace. WS2 will enable them to visualize previous design proposals in a 1/1 scale and to give feedbacks on current or previous work. Through WS1, they will be able to make their own proposals in a god like view.

Each step receives information from step (4); which is supported by WS3, the professional workspace. The information flow is bidirectional as well, since information can come as input/ouput from professionals to citizens and from citizens to professional.

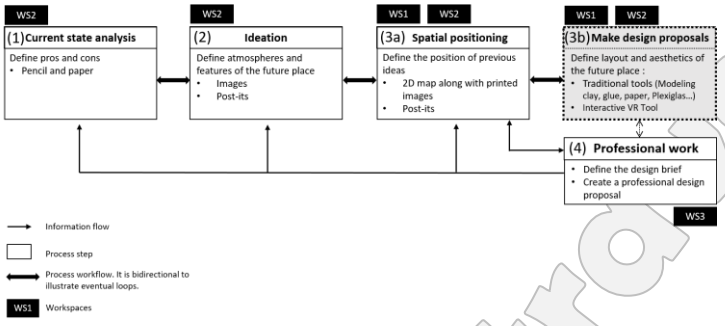

Fig. 6. Articulation of participation process with the conceptual framework

The following section will propose an implantation with a prototype for WS1 and WS2.

4.3 Software Architecture and User Interface

To follow on the design-science methodology, we propose the implementation of the artefact through a prototype. The aim of the prototype is to demonstrate the artefact's suitability with current context [51]. Fig. **7** presents the software architecture of the interactive and immersive artefact, which rests on Unity3D software along with a touch table and a head-mounted device. Unity is a widespread game engine which can easily support 3D visualization and interaction definition by scripting, and is well suited for an urban design tool [28]. The usage of table for the creation workspace seems well-suited to engage discussion and exchange ideas. It supports a circular configuration of multiple subgroups [38], collaboration and parallel problem solving [50]. Well-defined tactile interactions offer a more fluid and intuitive experience than the combination of a mouse and a keyboard [50]. Therefore, we chose to build a touchscreen-based solution for the creation workspace ((1) in Fig. **8**). Moreover, we believe this technological choice is the best suited to support collective creativity in urban design compared to the solution of augmented reality and tangible interfaces [14, 48, 60, 61] that support collective negotiation.

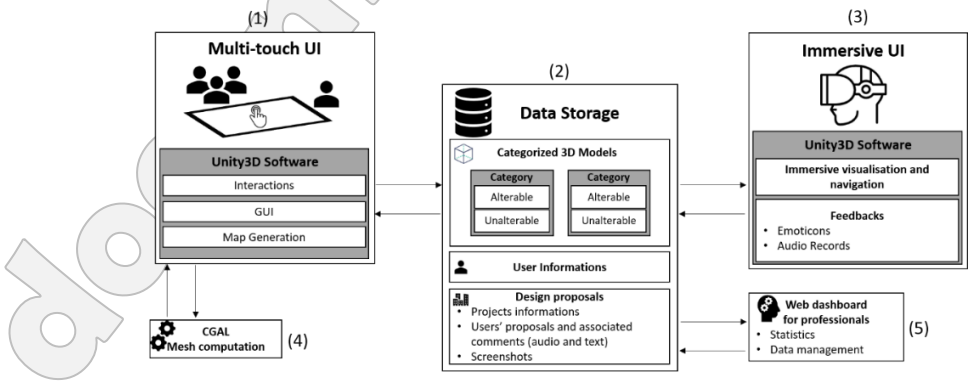

Fig. 7. Overview of software architecture

To generate the initial map along with streets and infrastructures, we use a Unity plugin called MapBox, which gathers data from the Open Source platform OpenStreetMap to generate a 3D environment with the provided geocoordinates. Image (1) of Fig. **8** illustrates the user interface developed with Unity3D editor. The camera point of view is a bird-eye view. From this interface, a user has access to the following interactions:

- Move camera (one finger drag)
- Zoom camera (two fingers)
- Select/unselect object (double tap)

- Move a selected object (one finger drag)
- Scale a selected object (two fingers pinch)
- Rotate a selected object (tree fingers drag)
- Edit a selected object: edition consists in slicing a 3D element in two different parts. It is the implementation of the "cut and paste" metaphor. To do so, the user need to draw a line over the model to extract the desired part (Figure X).

To implement the slicing operation, we developed a C++ plugin using CGAL Open Source library ((4) in Fig. **7**), which receives as input two *.off* files: the model and the line drawn by the user and two transformation matrixes extracted from Unity. The plugin then returns the two slices of the object.

Additional interactions are available through touch buttons: delete, duplicate, change color, change metadata (title and description) of a selected object. The user also has access to a 3D model database, allowing to add additional elements to the environment. Finally, each user can save its work in order to continue later if needed.

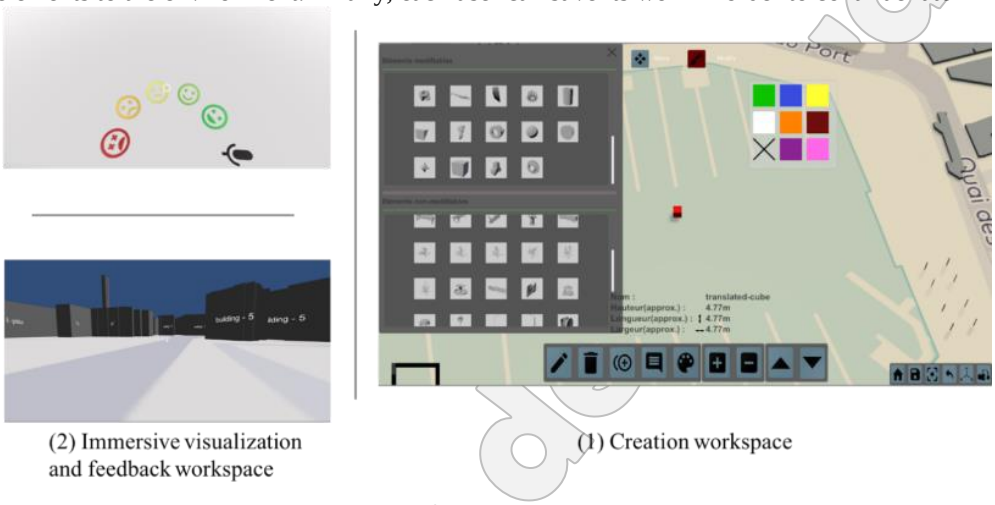

Fig. 8. Snapshots of the different workspaces

To instantiate the immersive visualization workspace ((3) in Fig. **7**), we propose to use a Head Mounted Display, such as a low-cost cardboard or a high-end device as an HTC Vive. Our prototype uses a Cardboard, hence we are currently limited with interactions. Through this environment ((2) of Fig. **8**), a user can explore his/her or someone else's proposal, either with an 1/1 scale view or with a bird-eye view. The available interactions are only feedback actions:

- Associate an emoticon to a selected object
- Associate an audio record to a selected object

The professional workspace ((5) in Fig. **7**) is accessible via a web interface, as presented in the third image of Fig. **8**. From this interface a professional can study all feedbacks, in the form of emoticons or audio recordings.

Finally, all the data (3D models, User information and saved Design proposal) are stored in a central database system ((2) in Fig. **7**).

Criterion number	Definition	Supported characteristic(s)	Associated requirement(s)
1	Reconstitutes the surrounding area of the future place: streets, buildings, contextual information (street names, building names, …)	Spatial awareness and comprehension	a), c), d), j)
2	Offers the opportunity to explore the future place with bird's eye view (zoom in/out, move camera)	Spatial awareness and comprehension	a), c), d), j)
3	Offers the opportunity for immersive visualization (scale 1:1 with a Head Mounted Display)	Spatial awareness and comprehension	a), c), d), j)
4	Offers the opportunity to annotate/categorize 3D elements (metadata)	Idea expression and feedback	g), h)
5	Offers the opportunity to manipulate 3D elements (move, scale, rotate, delete, change color/material)	Idea expression and feedback, Creativity	b), e), i), l)
6	Offers the opportunity to add new 3D elements in the virtual site (both abstract and complex shapes)	Creativity	e), k), l)
7	Offers the opportunity to edit 3D elements: cut and assemble	Creativity	e), l)

8	Offers an interactive and collaborative interface via touch screen	Collaboration, Co-creation	a)

Table 1. Comparison criteria derived from the analysis of the Environment

5 Discussion and Future Work

To situate our contribution with respect to identified literature (presented in section 2), we compare our work against 8 criteria defined on the basis of the requirements a) to l) (Section 4). Each criterion contains a needed characteristic for the definition of a collaborative ICT tool for PP in urban design. Table 1 provides an overview of each criterion with associated characteristic and requirement.

Table 2 shows our differentiation compared to the state of the art. The comparison clearly highlights that little attention is payed to co-creation by providing necessary tools, metaphors and interactions (criteria 5 to 7). The proposed artefact fills this gap. Furthermore, compared to the majority of the contributions in Computer Science and Information Systems, we are placing the artifact in articulation with a well-defined participatory process.

Regarding social sustainability research field, our work contributes to strengthen citizen's impact in the collective negotiation process by providing them an appropriate tool during the different steps of the participation process.

	Criterion number							
Reference	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
[47]	N	N	P	P	N	N	N	N
[39]	P	Y	N	N	P	P	N	N
[32]	Y	Y	P	Y	Y	Y	N	N
[58]	Y	Y	P	Y	N	N	N	N
[22]	N	N	N	Y	N	N	N	N
[21]	P	Y	Y	N	Y	P	N	N
[38]	Y	Y	N	N	N	N	N	Y
[20]	N	Y	Y	N	Y	Y	P	N
[17]	N	N	P	Y	Y	P	N	N
Our artefact	Y	Y	Y	Y	Y	Y	Y	P

Table 2. Evaluation of existing artefacts for PP in urban design. Y: criterion is respected, N: criterion is not respected, P: criterion is partially respected.

5.1 Evaluation of Research

This section applies the Design Science evaluation guidelines from Hevner et al. [26] to the research project. The goal is to show how the research (including the process and the product) satisfies each of the criteria. This exercise also clarifies our contribution to knowledge in Information Systems.

Problem Relevance

> *The objective of design-science research is to develop technology-based solutions to important and relevant business problems. [26], p. 7-8*

Problem relevance is exposed in section 1 and 2. Professional interviews and observational studies enabled us to identify the need for new ways of interaction for citizen during public participations in urban design. The analysis of previous research also show that work needs to be done to support generative design concepts in ICT tools for PP.

Research Rigor

Design science research requires the application of rigorous methods in both the construction and evaluation of the design artifact. Often empirical methods are needed to evaluate the artifact as part of a complete human-machine system. [26], *p. 8-9*

Our artifact is based on past research in the field of ICT-mediated citizen participation. This research area has a long history of formal, rigorous results that have been applied to the design of many artifacts.

We acknowledge the limitations of the interpretivist epistemological stance: interpretations of the observed environment are bound with our subjective experience. We attempted to control our own subjectivity by combining the field observations with recommendations collected from theoretical and methodological literature.

Design as a Search Process

The search for an optimal design is often intractable for realistic information systems problems. Heuristic search strategies produce feasible, good designs that can be implemented in the business environment. Decomposition of complex problems is an effective heuristic in the search for effective designs. [26], *p. 10-11*

A clear step by step process is used to design the presented artefact. First, we realized a survey in the literature to identify essential requirements for the artefact. We then enhance the requirements with an ethnological process composed of observational studies of a real project, interviews and focus groups. An evaluation process is defined in terms of usability and utility of the artefact. A conceptual framework is presented and articulated with an extended participation process and finally, a first instantiation of the artefact through a prototype (architecture and user interface).

Design as an Artifact

Design-science research must produce a viable artefact in the form of a construct, a model, a method, or an instantiation. [26], *p. 11-13*

As outlined in Section 4, the artefact is a *framework* comprising of a conceptual model, a method (the participation process) and an instantiation. The viability of the artefact is claimed in the fact that it can be expressed and applied to a problem domain. Further, its feasibility is argued from the prototype itself.

Design Evaluation

The utility, quality, and efficacy of a design artefact must be rigorously demonstrated via well-executed evaluation methods. [26], *p. 13-16*

An evaluation process is described but has not been conducted yet. This is a strong drawback of the paper that will be fixed in future work.

Research Contributions

Effective design science research must provide clear contributions in the areas of the design artifact, design construction knowledge, and/or design evaluation knowledge. [26], *p. 16-17*

We presented the design process and results of an IIVE to support citizen participation in urban design as well as its instantiation through a first prototype. Such contribution is considered as an improvement to knowledge in Information Systems through design-science research, as we proposed a new solution to a known problem : *The goal of DSR in the improvement quadrant is to create better solutions in the form of more efficient and effective products, processes, services, technologies, or ideas ...Situated instantiations (Level 1) are often constructed to evaluate the level of improvements in comparison with instantiations of the existing solution artifacts.* [25], *p. 346.*

5.2 Future Work

Our future work will be focused on a qualitative and quantitative evaluation of the artefact through simulated scenario workshops to evaluate its utility regarding creativity support. To ensure that the artefact is easy to handle for non-trained participants, another evaluation will be focused on the artefact's usability by running unipersonal tests along with questionnaires and video recordings. We will follow the "Prototyping Pattern" of DSR defined by [51], which consists in in 4 steps : specification of the artefact design, implementation of the artefact, realization of a test case with "real users" accomplishing a "real task" within our organizational context, and assessment of whether the task could be solved as intended by using the prototype.

We'll also follow the guidelines for collaborative interfaces from literature since our artefact instantiation doesn't fully respect yet the multi user interactions (criterion 8). Finally, we'll deepen our work on data extraction and visualization for professionals.

6 Conclusions

In this paper we presented the design and software architecture of an interactive virtual environment to support citizen participation and creativity in urban design. We payed particular attention to define an artefact intended for face-to-face workshops, helping citizens to creatively express their explicit and latent expectations of future public spaces. The advantage of our contribution is to bridge knowledge from urban design field about participatory processes in the form of an extended participation process, with knowledge from Computer Science and Information Systems fields about digital artefact design in the form of a design process and requirements. Gathering these two fields enabled us to propose a digital solution to different steps of a PP process. We also considered guidelines from generative design research in our functionalities to ensure creativity of participants. Finally, we proposed an implementation of the artefact by presenting our work in terms of user interface and software architecture.

We built our solution considering current advances in immersive and interactive technologies such as touch screens and head mounted displays.

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7 References

1. Adikari, S., McDonald, C., Collings, P.: A design science approach to an HCI research project. In: Proceedings of the 20th conference of the computer-human interaction special interest group (CHISIG) of Australia on Computer-human interaction: design: activities, artefacts and environments - OZCHI '06. p. 429. ACM Press, New York, New York, USA (2007)
2. Al-Kodmany, K.: Combining Digital and Traditional Visualisation Techniques in Community-Based Planning and Design. Digit. Creat. 10 (2), 91-103 (1999)
3. Al-Kodmany, K.: Public participation: Technology and democracy, https://www.tandfonline.com/doi/full/10.1162/104648800564635, (2000)
4. Al-Kodmany, K.: Using visualization techniques for enhancing public participation in planning and design: Process, implementation, and evaluation. Landsc. Urban Plan. 45 (1), 37-45 (1999)
5. Al-Kodmany, K.: Visualization tools and methods in community planning: From freehand sketches to virtual reality. J. Plan. Lit. 17 (2), 189-211 (2002)
6. Allard-Poesi, F., others: Coder les données. Conduire un Proj. Rech. une Perspect. Qual. 245-290 (2003)
7. Allard-Poesi, F., Perret, V.: Conduire un projet de recherche. Une approche qualitative. HAL (2004)
8. Alrashed, T., Almalki, A., Aldawood, S., Alhindi, T., Winder, I., Noyman, A., Alfaris, A., Alwabil, A.: An Observational Study of Usability in Collaborative Tangible Interfaces for Complex Planning Systems. Procedia Manuf. 3 1974-1980 (2015)
9. Arnstein, S.R.: A Ladder Of Citizen Participation. J. Am. Plan. Assoc. 35 (4), 216-224 (1969)
10. Assila, A.: Une approche et un outil pour l ' évaluation subjective et objective de l ' utilisabilité des systèmes interactifs : application à un système d ' aide à l ' information voyageurs Ahlem Assila To cite this version : HAL Id : tel-01411235. (2016)

11. Beck, K., Beedle, M., Bennekum, A. van, Cockburn, A., Cunningham, W., Fowler, M., Martin, R.C., Mellor, S., Thomas, D., Grenning, J., Highsmith, J., Hunt, A., Jeffries, R., Kern, J., Marick, B., Schwaber, K., Sutherland, J.: Manifesto for agile software development. (2001)
12. Ben-Joseph, E., Ishii, H., Underkoffler, J., Piper, B., Yeung, L.: Urban simulation and the luminous planning table: Bridging the gap between the digital and the tangible. J. Plan. Educ. Res. 21 (2), 196-203 (2001)
13. Billger, M., Thuvander, L., Wästberg, B.S.: In search of visualization challenges: The development and implementation of visualization tools for supporting dialogue in urban planning processes. Environ. Plan. B Urban Anal. City Sci. 44 (6), 1012-1035 (2017)
14. Broll, W., Lindt, I., Ohlenburg, J., Wittkämper, M., Yuan, C., Novotny, T., Fatah Gen Schieck, A., Mottram, C., Strothmann, A.: ARTHUR: A collaborative augmented environment for architectural design and urban planning. J. Virtual Real. Broadcast. 1 (1), 1-10 (2004)
15. Carroll, E.A., Latulipe, C.: The creativity support index. In: Proceedings of the 27th international conference extended abstracts on Human factors in computing systems - CHI EA '09. p. 4009. ACM Press, New York, New York, USA (2009)
16. Cherry, E., Latulipe, C.: Quantifying the Creativity Support of Digital Tools through the Creativity Support Index. ACM Trans. Comput. Interact. 21 (4), 1-25 (2014)
17. deVries, B., Tabak, V., Achten, H., De Vries, B.: Interactive Urban Design using integrated planning requirements control. Autom. Constr. 14 (2), 207-213 (2005)
18. DeWalt, K.M., DeWalt, B.R.: Participant observation: a guide for fieldworkers. , Walnut Creek (2002)
19. DeWalt, K.M., DeWalt, B.R.: Participant observation. In: Bernard, H.R. et Gravlee, C.C. (éd.) Handbook of methods in cultural anthropology. p. 259-300. Rowman Littlefield, Walnut Creek (1998)
20. Fatah, A., Schieck, G., Penn, A., Mottram, C., Strothmann, A., Ohlenburg, J., Broll, W., Aish, F.: Interactive Space Generation through Play Exploring Form Creation and the Role of Simulation on the Design Table. Int. J. Archit. Comput. 3. (2005)
21. G.a, D., M.b, R., A.c, R., N.c, T.: Design and evaluation of a real-world virtual environment for architecture and urban planning. Presence Teleoperators Virtual Environ. 16 (3), 318-332 (2007)
22. Gaborit, N., Howard, T.: A collaborative virtual environment for public consultation in the urban planning process. In: Proceedings - Theory and Practice of Computer Graphics 2004. p. 104-111. IEEE (2004)
23. Hanzl, M.: Information technology as a tool for public participation in urban planning: a review of experiments and potentials. Des. Stud. 28 (3), 289-307 (2007)
24. Hart, S.G., Staveland, L.E.: Development of NASA-TLX (Task Load Index). Adv. Psychol. 52 139-183 (1988)
25. Hevner, A.R., Gregor, S.: Positioning and Preenting Design Science: Types of Knowledge in Design Science Research. MIS Q. 37 (2), 337-355 (2013)
26. Hevner, A.R., Park, J., Ram, S., March, S.T., Park, J., Ram, S.: Design Science in Information Systems Research. Des. Sci. IS Res. MIS Q. 28 (1), 75-105 (2004)
27. Hurtienne, J., Naumann, A.: QUESI - A questionnaire for measuring the subjective consequences of intuitive use. Interdiscip. Coll. 2010. Focus Theme Play. Act Learn. 539 (2010)
28. Indraprastha, A., Shinozaki, M.: The Investigation on Using Unity3D Game Engine in Urban Design Study. ITB J. Inf. Commun. Technol. 3 (1), 1-18 (2009)
29. Jutraž, A., Moine, J. Le: Breaking out: New freedoms in urban (re) design work by adding immersive environments. Int. J. Archit. Comput. 14 (2), 103-118 (2016)
30. Jutraz, A., Zupancic, T.: Digital System Of Tools For Public Participation And Education In Urban Design Exploring 3D ICC. In: ECAADE 2012, VOL 1: DIGITAL PHYSICALITY. p. 383-392. (2012)
31. Jutraz, A., Zupancic, T.: Virtual worlds as support tools for public engagement in urban design. In: Planning Support Systems and Smart Cities. p. 391-408. Springer (2015)
32. Khan, Z., Ludlow, D., Loibl, W., Soomro, K.: ICT enabled participatory urban planning and policy development. Transform. Gov. People, Process Policy. 8 (2), 205-229 (2014)
33. Kniberg, H., Skarin, M.: Kanban and Scrum-making the most of both. Lulu. com (2010)
34. de La Ville, V.I., others: La recherche idiographique en management stratégique: une pratique en quête de méthode? Financ. contrôle Strat. 3 (3), 73-99 (2000)
35. De Lange, M., De Wall, M.: Owning the city: New media and citizen engagement in urban design. First Monday. 18 (11-4), (2013)
36. Lindell, R.: The Craft of Programming Interaction rnd engineering market. In: Proceedings of International Workshop on the Interplay between User Experience Evaluation and Software Development (I-UxSED 2012). p. 26-30. (2012)

37. Luigi, M., Massimiliano, M., Aniello, P., Gennaro, R., Virginia, P.R.: On the Validity of Immersive Virtual Reality as Tool for Multisensory Evaluation of Urban Spaces. Energy Procedia. 78 471-476 (2015)
38. Maquil, V., Leopold, U., De Sousa, L.M., Schwartz, L., Tobias, E.: Towards a framework for geospatial tangible user interfaces in collaborative urban planning. J. Geogr. Syst. 20 (2), 185-206 (2018)
39. Mueller, J., Lu, H., Chirkin, A., Klein, B., Schmitt, G.: Citizen Design Science: A strategy for crowd-creative urban design. Cities. 72 181-188 (2018)
40. Orlikowski, W.J., Baroudi, J.J.: Studying Information Technology in Organizations: Research Approaches and Assumptions. Inf. Syst. Res. 2 (1), 1-28 (1991)
41. Orlikowski, W.J., Iacono, C.S.: Research Commentary: Desperately Seeking the «IT »in IT Research - A Call to Theorizing the IT Artifact. Inf. Syst. Res. 12 (2), 121-134 (2001)
42. Peffers, K., Tuunanen, T., Gengler, C.E., Rossi, M., Hui, W., Virtanen, V., Bragge, J.: The Design Science Research Process: A Model for Producing and Presenting Information Systems Research. In: The Proceedings of Design Research in Information Systems and Technology DESRIST 2006. p. 83–106. (2006)
43. Preece, J., Rogers, Y., Sharp, H.: Interaction design: beyond human-computer interaction. John Wiley & Sons (2015)
44. Saad-Sulonen, J.C., Horelli, L.: The value of Community Informatics to participatory urban planning and design: a case-study in Helsinki. J. Community Informatics. 6 (2), (2010)
45. Sanders, E.B.-N., Stappers, P.J.: Co-creation and the new landscapes of design. CoDesign. 4 (1), 5-18 (2008)
46. Sanders, E.B., Stappers, P.J.: Convivial Toolbox. (2012)
47. Van Schaik, P.: Using interactive 3-D visualization for public consultation. Interact. Comput. 22 (6), 556-568 (2010)
48. Seichter, H.: Augmented Reality and Tangible Interfaces in Collaborative Urban Design. In: Computer-Aided Architectural Design Futures (CAADFutures) 2007. p. 3-16. Springer Netherlands, Dordrecht (2007)
49. Seichter, H.: Sketchand+ A collaborative augmented reality sketching application. In: Proceedings of the Conference on Computer-Aided Architectural Design Research. p. 209-219. , Bangkok (2003)
50. Shen, C., Ryall, K., Forlines, C., Esenther, A., Vernier, F., Everitt, K., Wu, M., Wigdor, D., Morris, M.R., Hancock, M., Tse, E.: Informing the Design of Direct-Touch Tabletops. (2006)
51. Sonnenberg, C., Vom Brocke, J.: Evaluation patterns for design science research artefacts. In: Communications in Computer and Information Science. p. 71-83. Springer, Berlin, Heidelberg (2012)
52. Spinuzzi, C.: The methodology of participatory design. Tech. Commun. 52 (2), 163-174 (2005)
53. Turan, S.Ö., Pulatkan, M., Beyazlı, D., Özen, B.S.: User Evaluation of the Urban Park Design Implementation with Participatory Approach Process. Procedia - Soc. Behav. Sci. 216 306-315 (2016)
54. Voinov, A., Kolagani, N., McCall, M.K., Glynn, P.D., Kragt, M.E., Ostermann, F.O., Pierce, S.A., Ramu, P.: Modelling with stakeholders - Next generation, http://linkinghub.elsevier.com/retrieve/pii/S1364815215301055, (2016)
55. Wates, Nick, Brook, Jeremy, De Lange, M., De Waal, M., Salter, J.D., Campbell, C., Journeay, M., Sheppard, S.R.J., Yeang, L.D., others, Jutraz, A., Zupancic, T., Slotterback, C.S., Senbel, M., Church, S.P., Panagopoulos, T., Andrade, R. dos R., Barreira, A.P., Luigi, M., Massimiliano, M., Aniello, P., Gennaro, R., Virginia, P.R., Fonseca, D., Valls, F., Redondo, E., Villagrasa, S., Turan, S.Ö., Pulatkan, M., Beyazlı, D., Özen, B.S., Hanzl, M., Saad-Sulonen, J.C., Horelli, L., Ben-Joseph, E., Ishii, H., Underkoffler, J., Piper, B., Yeung, L., Köninger, A., Bartel, S., Ahn, H.-C., Jacobi, M., Halatsch, J., Kunze, A., Schmitt, G., Turkienicz, B.: The community planning handbook : how people can shape their cities, towns and villages in any part of the world. Springer (2000)
56. Westerberg, P., Von Heland, F.: Using minecraft for youth participation in urban design and governance. (2015)
57. Witmer, B.G., Singer, M.J.: Measuring Presence in Virtual Environments: A Presence Questionnaire. (1998)
58. Wu, H., He, Z., Gong, J.: A virtual globe-based 3D visualization and interactive framework for public participation in urban planning processes. Comput. Environ. Urban Syst. 34 (4), 291-298 (2010)
59. Yeang, L.D., others: Urban design compendium. English Partnerships/Housing Corp. London. (2000)
60. Changing places, http://cp.media.mit.edu/cityio/, Consulté le: juillet 01, 2017
61. Everyday Objects as Interface : Collaborative MouseHaus Table , a Physical Interface for Urban Design.