Immersive urban planning: Infusing virtual reality into citizen participation for amplified engagement and sustainable planning

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Abstract

Urban planning, a complex discipline shaping the spatial development of urban and rural areas, encounters challenges in citizen participation. Current participation methodologies lack structured processes, user-centric approaches, and user-friendly (digital) tools, leading to diminished citizen comprehension, reduced engagement, and suboptimal implementation of proposed measures. In response to these challenges, we have developed a Virtual Reality (VR) tool designed to involve citizens in the initial phases of the participation process, specifically the information phase.

A VR tool was designed with a focus on simplicity for novice users, location-independent accessibility for participation events in the field, and the incorporation of existing planning data with minimal effort. To assess the tool's effectiveness, we conducted prototype testing during two public information events related to the redesign of a park, involving a total of $N = 52$ participants.

Participants actively engaged with the VR tool and provided feedback on its suitability for the planning process. The results indicate that the tool was perceived as easy to use, and the VR environment was deemed appropriate for participatory contexts. This study demonstrates the potential of integrating VR into participatory processes, highlighting its efficacy in enhancing citizen understanding of planning content and fostering active engagement.

Introduction

Under terms like “citizen participation” or „citizen sourcing”, an adaptation of the crowdsourcing paradigm, researchers have been describing ways of involving citizens in public management and government tasks for well over a decade (Hilgers & Ihl, 2010; Dutton, 2011). Their arguments in favour of such processes are straight forward: they enable citizens to engage in different stages of governmental processes, build a shared understanding (intra-group as well as with government agencies) and enables large-scale decision-making – all leading to increased transparency, accountability, service orientation, perceivable output and outcome directly benefitting citizens (Li et al., 2020; Donders et al., 2014; Torres, 2007).

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City infrastructure projects in Germany follow the Design-Bid-Build (DBB) approach, which serves as a global standard for infrastructure projects, including those in the United States and Europe (Gashi & Marja, 2024; Tran et al., 2018). DBB projects adhere to a sequential process, where each task is completed before the next one begins, without any overlapping (c.f. figure 1). Citizens can be involved in each of these stages, either for informational purposes, to participate in design choices or to evaluate different planning options. In general, citizen participation is seen as a valuable part of urban planning, offering the opportunity to achieve more democratic, inclusive and effective urban development outcomes (Li et al., 2020; Donders et al., 2014). But urban planners are currently facing the challenge of matching unstructured and undefined citizen engagement with their well-structured internal process – and find the proper ICT tools to support the process and make it feasible (Schwarzkopf et al., 2023).

Without specifications, it is up to the planners to decide whether and when to involve citizens in the planning process. As participation is seen as time-consuming and costly and the positive contribution to the planning process is difficult to anticipate, it is often deliberately kept to a minimum, especially in early planning stages (Mishra & Maheshwari, 2023; Schwarzkopf et al., 2023).

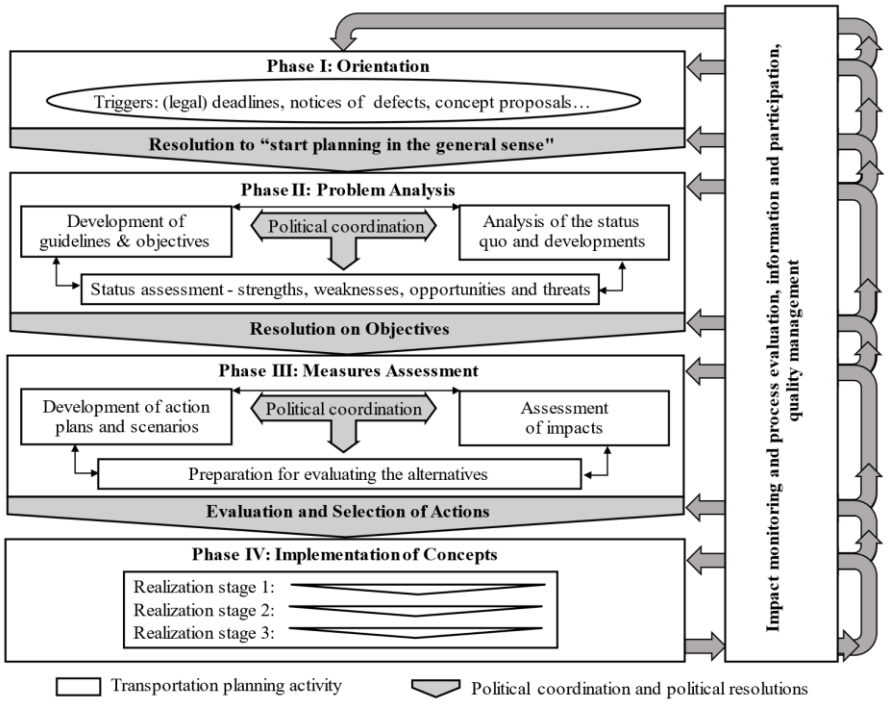

Figure 1. Schematic procedure for urban infrastructure planning processes in Germany; own translation, scheme according to FGSV18b (FGSV18b, 2018)

To address the issue of unstructured and undefined engagement of citizens Mishra & Maheshwari (2023) proposed a strategic framework of three steps (Preparation – Plan

and Design; Execution – Promote and Act; Post Execution – Evaluate and Feedback). Although this framework could be applied to all of the planning phases shown above, it lacks the appropriate methods and tools that can be easily adapted to the different phases.

Designing a VR tool for citizen participation

In the rapidly evolving landscape of technology, Virtual Reality (VR) has emerged as a powerful tool for engaging users in immersive experiences, transforming the way we interact with digital content and educational materials. Potential applications for urban planning have already been shown (Higuera-Trujillo et al., 2017; Wolf et al., 2020, Yao et al., 2021), also regarding citizen participation in planning processes (Mahbubur & Kitson, 2020; Wolf et al., 2020) as well as evaluation of completed infrastructure measures (Schwarzkopf et al., 2022).

In their literature review, Wolf et al. (2020) see the advantages of VR in citizen participation and evaluation in, among other things, the increased comprehensibility of planning content and processes, a direct evaluation regarding to the likelihood of use by citizens, the increase in motivation for participation and the possibility of integrating marginalized groups (e. g. children, people with physical disabilities, etc.). The use of VR can help to overcome the described problems in citizen participation processes especially in early planning stages. In general, VR technology allows citizens to visually experience and engage with urban design proposals, leading to improved understanding, participation motivation and interest. (Lee et al., 2018)

However, so far two essential things are missing to integrate VR into the planning and participation processes from the perspective of urban planners (Wolf et al., 2020; Schwarzkopf et al., 2023):

i) structured recommendations for action in which planning phases these support tools should be used
ii) low-threshold digital support tools that are integrated into the daily work of planning authorities and are available to both planners who provide methodological support and planning content in a way that is easy to understand and technically low-threshold for citizens

In the following sections we focus on conceptualising a prototype of a proposed solution for early planning stages which utilises the possibilities of virtual reality (VR) and highlights its accessibility in terms of user-friendliness and cost-effectiveness for local authorities.

Stakeholders and Requirements Elicitation

Stakeholders in urban planning vary depending on the context and the specific initiative or project in question. We distinguish between four major groups of relevant stakeholders as shown in table 1.

Table 1. Stakeholders for a digital support tool for planners in the field of citizen participation.

Stakeholder	Explanation
Planners	Planners are responsible for planning in accordance with laws and regulations and for managing any participation and communication processes. They do not have in-depth methodological knowledge for carrying out surveys and do not have the time and resources to test or develop innovative technologies for participation processes.
Legitimators	Politicians who endorse planning projects, make decisions regarding their funding, and may not possess the necessary terminology and knowledge to understand planning projects in detail. But they must possess a comprehensive understanding of potential consequences, particularly in the context of holistic city planning, as opposed to solely focusing on traffic issues or a specific project.
Users	Everyone who uses the completed measure (or not). Accordingly, the group of users consists of all social classes. However, they decide whether a planning project is socially integrated and whether it is a success from society's point of view.
Administrators	They define the planning steps, allocate finances and are responsible for the realization of the project. Ideally, this group should also include citizens if they have been integrated into the project planning at an early stage through participatory measures. At best, they create urban development measures that benefit society and its sustainable development.

During the requirement analysis phase for a citizen participation support tool for urban planners, a workshop with $N = 7$ experts and $N = 3$ individual interviews with experts from the fields of urban planning, citizen participation and citizen information were conducted. While these sessions were not exhaustive, they did identify critical needs as perceived by the urban planners. It was determined that a digital support tool should include the functional requirements outlined in Table 2 and the non-functional requirements detailed in Table 3.

Table 2. Functional Requirements. for a digital support tool for citizen participation for planners.

Functional Requirements (FR.)	Explanation
Conducting and evaluating surveys & providing easy-to-adapt surveys	Planners have insufficient skills in conducting surveys. The tool should support them with suggestions and guidelines.
Visualizing existing planning models (esp. CAD-Data) and planning views	The tool should be able to use existing data from urban planning and visualize it easily.
Making restrictions for people with disabilities visible (different visual filters, perspective of wheelchair users, etc.)	VR makes it possible to better understand the limitations of marginalized groups. These restrictions should and must be considered in urban planning.
Comparing different planning models	There will be various planning proposals and ideas. These should be easy to compare using the tool.
Evaluation of completed urban development measures	Evaluations of completed planning models are time-consuming and are therefore rarely carried out. The tool should provide an efficient platform for carrying out these evaluations.

Table 3. Non- Functional Requirements. for a digital support tool for planners in the field of citizen participation.

Non-Functional Requirements (N.-FR.)	Explanation
Easy to use for planners	The learning threshold of the tool must be low for planers and participations experts.
Easy to use for citizens	Both the hardware and the user interface should be intuitive to use and require minimal explanation. This applies to all groups of people, from children to the elderly.
Usable for people with impairments.	The tool must be usable for as many people as possible.
The tool must be transportable	The tool must function independently of the location. It must be able to be used both at large events and in confined spaces. The hardware must have a low weight and volume.
Easy to maintain by planners	Content (especially visualization data) must be easily and quickly exchangeable.
Performance	The tool should allow quick sessions without short loading times and no reload breaks in between each session.

VR tool design and implementation

Based on the requirements gathered from our interviews and the current state derived from literature, we designed a VR tool to be used for easy citizen participation in early stages of the urban planning process.

Our user study on this prototype was implemented in a virtual environment based on early CAD planning data for the redesign of an urban park, including a basketball court. These planning data were provided to us by the authorities in a raw state (it was for planning purposes, not for public information and therefore missing visual details), was imported and modified within Unity to include additional environmental elements like the surroundings of the park area and some visual improvements (figure 2). Additionally, we set up a selection of points of interest which pinpoint important views and elements within the virtual environment, which users could navigate to by pressing a button on the VR headset's controller. However, unrestricted navigation in the virtual environment was not provided. Participants were able to look around the virtual world by simply tilting or turning their heads. In addition, it was possible to change the height setting of the view, for example to adopt the perspective of children or wheelchair users.

For this project, it was the planners' primary goal to inform citizens to view the planning status of the park and to allow them to choose between different patterns and colours of the basketball court. We implemented the various options as textures on the basketball court model. Users were also able to switch between these options by pressing a button. The scenery was displayed in a self-developed Unity application on a PICO Neo 4 Enterprise VR headset with an integrated computing unit, which allowed us to carry out the study at any location.

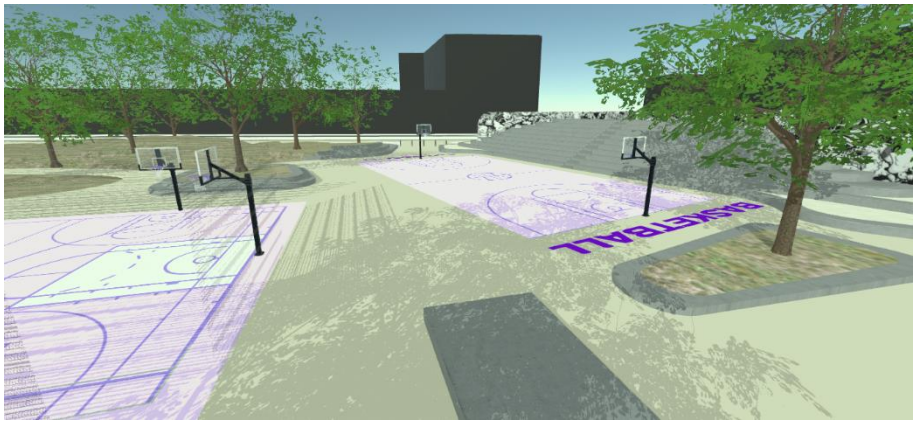

Figure 2. View on the basketball fields in VR

Evaluation & Results

Process

The evaluation procedure consisted of four phases and involved three groups; the process was identical for all groups. In Phase I, a brief introduction of one minute was given. In Phase II, participants were equipped with the headset and first shown five 360° images of the park's current state. This was done to provide individuals less familiar with the park an impression of its current condition and appearance. In Phase III, the virtual planning environment of the park was presented, and participants could explore it without a time limit, expressing their impressions via think-aloud. In Phase

IV, participants were surveyed about their use of technology, acceptance, and representativeness of the shown VR environment through a questionnaire. The questionnaires were filled out on tablets but are intended to be integrated into the VR tool in future participation processes. The complete evaluation process from phase I to IV took between seven to twelve minutes. The different experimental groups are explained in table 4.

Table 4. Presentation of the groups and the contexts of their participation

Group	Participants	Origin	Restrictions
I General Public	$N = 16$ $M_{age} = 23$	Random students in the canteen, no dedicated interest in citizen participation	No evaluation of the citizen participation
II Affected Parties – exclusive participation event	$N = 23$ $M_{age} = 28$	Citizens who have registered for a citizen participation event.	-
III Affected Parties – free participation event	$N = 13$ $M_{age} = 31$	Citizens who took part in a citizen participation event at the planning location without registering	-

Evaluation

Table 5. Evaluation of the technical aspects of Evaluation Group I, II, III & for all groups together (M_A). Evaluation in school marks (1 – very good, 6 – poor, $N_I = 16$; $N_{II} = 23$; $N_{III} = 13$; $N_A = 52$)

	M_I (SD)	M_{II} (SD)	M_{III} (SD)	M_A (SD)
How would you rate the practical suitability of the hardware used (virtual reality headset) in relation to the tour through the virtual environment?	1.68 (0.60)	1.52 (0.59)	1.90 (0,95)	1.67 (0.70)
How well were you able to rate the current state of the park with the help of the 360° images?	1.43 (0.51)	1.65 (0.71)	1.70 (0.63)	1.59 (0.63)
How suitable is the virtual environment for evaluating the redesign of the park?	1.68 (0.79)	1.35 (0.49)	2.00 (0.98)	1.57 (0.75)
How do you rate the ease of use of the technology?	1.12 (0.34)	1.35 (0.57)	1.30 (0.48)	1.27 (0.49)

In the first evaluation group, data was recorded with students within the confines of a canteen. These interviews were not associated with a participatory event, and $N_I = 16$ individuals participated in this setting. The second evaluation group involved surveying citizens at a participation event, which required prior registration and was

not held in the park subject to the planned changes, N_{II} = 23 participants attended in total. In the third group of evaluation, individuals were directly surveyed at the park that was the focus of the participation initiative, coinciding with a city festival. In this group N_{III} = 13 individuals participated on-site. The results regarding the perceived suitability of the tool as well as the ease of use for all groups can be found in Table 5.

Furthermore, during Evaluation II & III (N = 39), we inquired with the participants if they would consider using VR technology in the future. Approximately 88% of the participants concurred. About 92% acknowledged that the technology provided substantial added value over traditional analogue formats. The same level of concurrence was observed when participants were questioned if they would prefer using VR technology for civic engagement formats. No instances of motion sickness or similar complaints were reported or observed among the participants.

Conclusion & Future Work

The results of the evaluation showed that the prototype VR tool was well received by participants, scoring high in terms of the technology's suitability for participatory processes and its ease of use, regardless of the age of the subjects. The feedback indicates that the tool may made the presented planning state more accessible and understandable to the participants even in an early stage. Participants also expressed a desire to use VR more frequently in the context of participation and information processes, suggesting that the tool could be a valuable asset for education and civic engagement in the future. Citizens can gain a better understanding of the current planning phase and how the planned design might look and feel. So, the tool enables effective participation, as needs and desires can be articulated in a targeted manner by the citizens. Planners, in turn, can address challenges in a targeted way, aiding them in managing current and future planning projects. As mentioned at the beginning, resources and time are scarce in urban planning. The content presented in the current VR Tool did not need to be created from scratch, as it was based on existing CAD data from the planning project. Editing in Unity took us about five hours (e.g. adding colour schemes, more realistic trees and shapes of the surroundings). This time could be significantly reduced if standards for the creation of planning data by architecture companies or officials were adapted. Then, corresponding data sets could be directly loaded into Unity or the VR app and used for participation and information processes. This could pave the way for VR as a simple, effective, motivating, but above all, suitable method for participation processes.

We are continuing to refine the tool for urban planners, focusing primarily on simplifying the evaluation process and data analysis for planners. One approach could involve integrating pre-designed questionnaire modules into the tool, which would be displayed in VR and subsequently analysed automatically. Moreover, it is crucial that data are prepared by urban planners or external firms in such a way that they can be directly applied in VR. This should be a streamlined process that requires minimal time to complete. Additionally, we want to incorporate filters that allow for the simulation of visual impairments, thereby enabling an understanding of the perspective of visually impaired individuals.

The overarching goal is to create an application and formulate recommendations for actions that can provide structured support throughout the entire planning process. To this end, the app could process not only CAD data but also 360-degree images and videos. Ideally, the data contained within could be viewed on mobile devices and home computers, enabling a direct and structured exchange with the planners.

In conclusion, the evaluation of the design choices and implementation of the novel VR tool for engaging citizens in the planning process of new constructions has shown promising results. The tool has been helped enhancing the understanding and awareness of the current planning phase among the participants at an early stage. The feedback from the evaluation phase provides valuable insights into the potential of VR technology in civic engagement and education, paving the way for further development and application of VR tools in similar contexts.

Limitations

Limitations observed during the project include various factors affecting participation and data collection. Firstly, while there was a noticeable motivation among participants in the citizen participation exercises, this may not uniformly represent the wider population's willingness to engage in such activities. So, the evaluation of the participation presented in this paper may be biased. Secondly, using and showing the VR headset on participation events to interested citizens might have inadvertently influenced participation; individuals with a predisposition against such technology were deterred from even attempting to use it and vice versa. This creates a selection bias where only those comfortable with or curious about VR technology participated, which might limit the diversity of the feedback received. Additionally, the 'Wow-Effect' – or the initial astonishment provoked by the novel technology – could potentially overshadow the content and purpose of the exercise (Shelstad et al., 2017). Participants may become more focused on the novelty of the technology rather than the substance of the participation exercise, which could affect the quality and seriousness of their engagement. Lastly, the data collection focused on the gathering of subjective evaluations, which, while valuable, can introduce a range of biases. Subjective data relies heavily on personal opinion and perception, which can be influenced by a multitude of factors, not all of which are directly related to the citizen participation activities. Therefore, while subjective evaluations are integral, supplementing them with objective data could provide a more comprehensive understanding of the participatory process and its outcomes.

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References

Donders, M., Hartmann, T., & Kokx, A. (2014). E-participation in urban planning: Getting and keeping citizens involved. *International Journal of E-Planning Research (IJEPR), 3(2), 54-69.* https://doi.org/10.4018/ijepr.2014040104

Dutton, W.H. (2010). Networking distributed public expertise: strategies for citizen sourcing advice to government. *One of a Series of Occasional Papers in Science and Technology Policy, Science and Technology Policy Institute, Institute for Defense Analyses, Pennsylvania Avenue, Washington DC.*

Gashi, E., & Ivezaj, M. (2024). Quality management for design–Bid-build versus design-and-build contracts for infrastructure projects. *International Review of Applied Sciences and Engineering, 15(1), 130-137.* https://doi.org/1848.2023.00730

Higuera-Trujillo, J.L., Maldonado, J.L.T., & Millán, C.L. (2017). Psychological and physiological human responses to simulated and real environments: A comparison between Photographs, 360 Panoramas, and Virtual Reality. *Applied Ergonomics, 65, 398-409.* https://doi.org/10.1016/j.apergo.2017.05.006

Hilgers, D., & Ihl, C. (2010). Citizensourcing: Applying the concept of open innovation to the public sector. *International Journal of Public Participation, 4*, 67-88.

Li, W., Feng, T., Timmermans, H., Li, Z., Zhang, M., & Li, B. (2020). Analysis of citizens' motivation and participation intention in urban planning. *Cities, 106, 102921*. https://doi.org/10.1016/J.CITIES.2020.102921

Mahbubur, M., & Kitson, J. (2020). Using multi-sensory and multi-dimensional immersive virtual reality in participatory planning. *Urban Science, 4(3), 34.* https://doi.org/10.3390/urbansci4030034

Mishra, D., & Maheshwari, N. (2023). Effective Governance Through Crowdsourcing: A Strategic Framework for Empowered Participation. *IEEE Transactions on Engineering Management* https://doi.org/10.1109/TEM.2022.3218188

Lee, S., Eo, S., Ryu, K. & Kim, Y. (2018). Using Virtual Reality in Design of Street Space by Citizen Participation. *Journal of the Korea Academia Industrial Cooperation Society, 19,* 77-85. https://doi.org/10.5762/KAIS.2018.19.2.77

Schwarzkopf, M., Dettmann, A., Trezl, J., & Bullinger, A.C. (2022). Do you bike virtually safe? An explorative VR study assessing the safety of bicycle infrastructure. In D. de Waard, S.H. Fairclough, K.A. Brookhuis, D. Manzey, L. Onnasch, A. Naumann, R. Wiczorek, F. Di Nocera, S. Röttger & A. Toffetti (Eds.), *Proceedings of the Human Factors and Ergonomics Society Europe Chapter 2022 Annual Conference: Enhancing Safety Critical Performance (pp. 101-110). Human Factors and Ergonomics Society.* https://www.hfes-europe.org/largefiles/proceedingshfeseurope2022.pdf

Schwarzkopf, M., Dettmann, A., Heinz, A., Miethe, M., Hoffmann, H. & Bullinger, A.C. (2023). Let's Use VR! A Focus Group Study on Challenges and Opportunities for Citizen Participation in Traffic Planning. *HCII 2023, Part I, LNCS 14048.* https://doi.org/10.1007/978-3-031-35678-0_24

Shelstad, W., Smith, D., & Chaparro, B. (2017). Gaming on the Rift: How Virtual Reality Affects Game User Satisfaction. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 61, 2072 - 2076.* https://doi.org/10.1177/1541931213602001

Torres, L. H. (2007). Citizen sourcing in the public interest. *Knowledge Management for Development Journal,* 3(1), 134-145.

Tran, D.Q., Diraviam, G., & Minchin Jr, R.E. (2018). Performance of highway design-bid-build and design-build projects by work types. *Journal of Construction Engineering and Management, 144(2),* 04017112. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001437

Wolf, M., Söbke, H., Wehking, F. (2020). Mixed Reality Media-Enabled Public Participation in Urban Planning. *In: Jung, T., tom Dieck, M.C., Rauschnabel, P.A. (eds) Augmented Reality and Virtual Reality. Progress in IS. Springer, Cham.* https://doi.org/10.1007/978-3-030-37869-1_11

Yao, G., Yuan, T., Rui, Y., Chen, W., Duan, Z., Sun, L. & Chen, Y. (2021). Research on the scale of pedestrian space in underground shopping streets based on VR experiment. *Journal of Asian Architecture and Building Engineering, 20(2), 138-153.* https://doi.org/10.1080/13467581.2020.1782215