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A Comparison of Hand-Held AR and VR for On-Site Assessment of Construction Projects

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Abstract:

A major concern for city governments in urban planning processes in Switzerland is the increasing number of building appeals. A possible cause is the complexity of urban developments and the assessment of possible impacts of planned constructions by the general, non-professional population. When applying for a construction permit, developers must publicly announce the planned buildings by mounting a framework of construction poles that delineate the volume of the planned structures to inform residents about potential impacts in their neighborhood. However, these building frameworks are not very intuitive (Boos et al., 2022). A better visualization of the projects with extended reality (XR) technologies could help alleviate the current situation and make it easier for residents to participate in the planning process of their neighborhood.

With this research, we investigate how XR affects our understanding of construction projects and how it can be effectively used as a tool for participatory urban planning. We designed and conducted a user study to assess how augmented reality (AR) and virtual reality (VR) hand-held displays might differ regarding the perception of development projects in the context of the Swiss construction approval process. The following two research questions are addressed: **(RQ1)** Does the selection of hand-held AR vs. VR as a tool for the on-site visualization of construction projects affect the user's perception of the project? **(RQ2)** Does the use of AR vs. VR affect the decision to file a building appeal against a development project? We hypothesize that AR will give a better understanding of the construction project due to its immersive character and situatedness in the construction environment, generate more confidence in the visualization, and will reduce the number of appeals compared to VR.

To answer these research questions, we designed a field study and developed an app that showed a planned building as AR and VR on a mobile device that participants had to assess (see Fig. 1). The prototypes were developed using the Unity engine, Google's ARCore service, Google's visual positioning system and Cesium for Unity. To be as realistic as possible, the planned construction project was based on an existing building complex in the city of Zurich, consisting of a high-rise (20 floors; 64 meters high) and a low-rise building (5 floors; 16 meters high) with a footprint of 54 meters width and 72 meters length. This combination fits the environment of the construction site, consisting of a mix of high-rise and low-rise buildings. The building model was extracted from the 3D city model of Zurich on LOD 2 (www.stadt-zuerich.ch/geodaten/download/Bauten___Blockmodell) and further modified using Blender. The virtual building was given a simple shape and a custom texture similar to the surrounding buildings. The virtual environment for the VR condition used Unity's default skybox showing a clear daytime sky (see Fig. 1). For the terrain, building, and vegetation, Google's Photorealistic 3D Tiles were chosen for their realistic textures, and high temporal and spatial resolution.

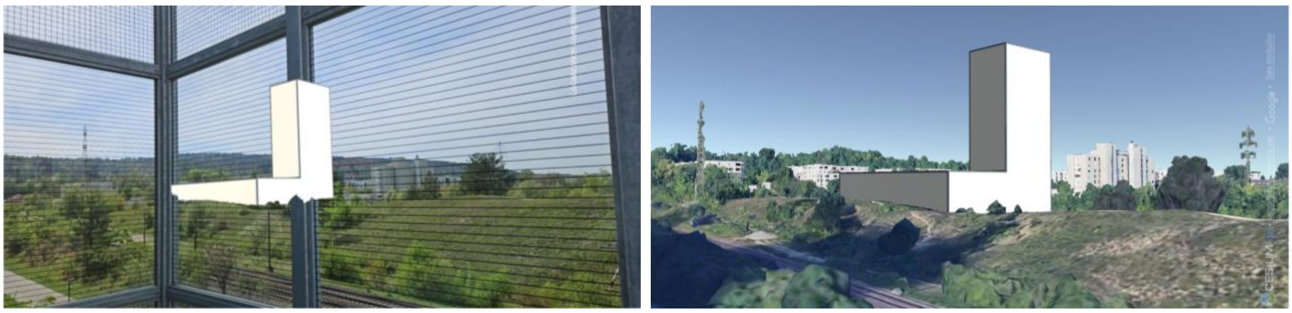

Figure 1. The planned building displayed in AR (left) and VR (right).

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The study followed a between-subject design with two conditions where the planned building was displayed either in AR or VR. Thus, participants were randomly split into two groups, each taking part in the experiment separately and only getting to see their respective prototype. In total, 42 participants were recruited through university mailing lists and through the personal network of the first author. Participation criteria were healthy adults over 18 years old with normal or corrected-to-normal vision, have no color blindness, and sufficient knowledge of German or English. Before the experiment, participants completed an online questionnaire used to collect their demographic data and experience with planning, geodata, and VR/AR technology. Participants gave written informed consent before the start of the study.

Both treatment groups had 21 participants in total, with AR having 9 females and 12 males and the VR group consisting of 10 females and 11 males. Participants' age ranged from 20 to 39 years old ($M = 27.5$, SD = 4.87). For AR, the values were $M = 28.0$, $SD = 4.92$, and in the case of VR, they were $M = 27.0$ and $SD = 4.89$. Most participants had experience with GIS and used their smartphones daily. Their experience with VR and AR was low, with only six participants stating they had moderate or extensive experience with AR, and eight participants for VR (AR: M =2.31, SD=1.05; VR: M =2.48, SD=1.17).

The field study took place in Zurich in March 2024. After welcoming the participants to the site, they were immersed in a fictional scenario envisaging them living close to the planned project, in a building from which the construction project would be seen. This was reinforced by visiting a real building that was supposed to be the participant's residence and looking at the virtual building from there. Participants then visualized the construction either in VR or AR on a Samsung Galaxy S23 smartphone running on Android 14. Next, participants had to complete the intra-experiment questionnaire, which included building dimension and floor estimation tasks. The questionnaire also included diverse statements regarding the participant's perception of the building and the visualization, what impact the project would have on its surroundings, and whether the participant would act toward filing a building appeal. The post-experiment questionnaire was to be answered retrospectively after having used the prototype and not having access to it anymore. It only contained statements in a 5-point Likert scale, encompassing statements related to the visualization and the app.

The results revealed no significant differences between AR and VR in how users perceive the fictitious development project. The only significant difference between AR and VR occurred when participants had to estimate the tower height from the roof deck 230 meters away ($t(39) = 2.346$, $p = .024$). The AR group overestimated ($M = 9.10$, $SD = 26.75$), while the VR group underestimated ($M = -8.52$, $SD = 21.15$) the 64-meter-high tower. An overestimation could exaggerate a negative impression on the user, while an underestimation could cause a positive impression that would benefit the developer. Since all other estimations were made from close-by, this finding suggests that the further away from an object, the harder it becomes to estimate its size. The overestimation of the AR group also coincides with the results from Boos et al. (2022), which suggests that this effect is inherent to this type of visualization. An interesting result of our study was that participants using AR tended to trust the visualization less, although not significantly less than in VR. One possible explanation for trust to score higher in the VR condition is that errors in the device's position and direction cause less disruption.

We did not find that the two tested conditions (AR vs. VR) affected the decision of participants to file a building appeal. Our results show no evidence of diverging perception or appeal behavior between the two conditions. The possible loss of open green space and aesthetics seem to play a bigger role in the decision process. Nonetheless, our study demonstrates the feasibility of effectively integrating XR technologies into urban planning processes under real-world conditions. As such, XR technologies may play a significant role to promote more inclusive and effective urban planning practices, enhancing the way cities handle public participation and the development of their built environment.

Although our study revealed valuable findings, it also has its limitations. We could not control for factors such as environmental conditions, weather, sudden increase in pedestrian traffic caused by the arrival of a packed train, the unexpected appearance of dog-owners or picnickers listening to loud music. Moreover, the sample size is rather small.

Ultimately, our findings let us conclude that the choice of AR or VR will not significantly affect the user experience and therefore other factors, like technical requirements, availability of resources and accessibility should take priority in the choice of technology.

References

Boos, U., Reichenbacher, T., Kiefer, P. and Sailer, C. (2022). An augmented reality study for public participation in urban planning. *Journal of Location Based Services*, *17*(1), pp. 48–77. DOI: 10.1080/17489725.2022.2086309.

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