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Evaluating Different Levels of Detail in AR for Enhancing Citizen Participation in Urban Planning

Lars Sievers, Frank Othengrafen, Luisa Nagel, Eva Reinecke

Abstract

The introduction of augmented reality (AR) into urban planning is becoming increasingly important as digital data and models allow urban planners to visualise their plans and concepts in a different way so that various stakeholders can view and experience the virtual changes to the structural and spatial structures immediately. This paper presents the results of an interdisciplinary research project in which an AR App was designed and evaluated in terms of its applicability, user-friendliness and added value for integrative participation. The evaluation of the AR App clearly emphasised that AR provides a more serious consideration of plans and concepts, since the user receives a realistic impression of plans and concepts 'live' on site. The fact that the participants are able to view and 'experience' the spatial structure, the building hights and distance spaces in the App is particularly appreciated by the participants as an added value. The level of detail (LOD) used for visualisation appears to be crucial here. The evaluation further highlights that participants generally prefer 3D models with an increased LOD, i.e. LOD 3.1 and 3.3, for visualisation in AR, as these are more appropriate for conveying a more comprehensive impression with regard to the intended spatial changes and detailed planning drafts. Higher LOD are thus preferred in the participation phase, as they can provide a better impression of the planning project.

Keywords:
augmented reality, level of detail, urban planning, digital participation, evaluation

Valutazione dei diversi livelli di dettaglio dell'AR per migliorare la partecipazione dei cittadini nella pianificazione urbana

L'introduzione della realtà aumentata (AR) nella pianificazione urbana sta diventando sempre più importante, in quanto i dati e i modelli digitali consentono agli urbanisti di visualizzare i loro piani e concetti in un modo diverso, affinché i vari soggetti interessati possano prendere visione e sperimentare nell'immediato le modifiche virtuali ai sistemi strutturali e spaziali. Questo articolo presenta i risultati di un progetto di ricerca interdisciplinare in cui è stata progettata e valutata un'applicazione AR in termini di applicabilità, facilità d'uso e valore aggiunto per la partecipazione integrata. La valutazione dell'applicazione AR ha chiaramente sottolineato che l'AR genera un più serio coinvolgimento nel processo pianificatorio, poiché l'utente esperisce un'impressione realistica di questi ultimi "dal vivo" in situ. Il fatto che i partecipanti siano in grado di visualizzare e "sperimentare" la struttura spaziale, le altezze degli edifici e le distanze reali nell'app è particolarmente apprezzato dagli utenti come valore aggiunto. Il livello di dettaglio (LOD) utilizzato per la visualizzazione sembra essere cruciale in questo caso. La valutazione evidenzia inoltre che i partecipanti preferiscono in genere modelli 3D con un LOD maggiore, cioè LOD 3.1 e 3.3, per la visualizzazione in AR, in quanto più adatti a trasmettere un'impressione completa riguardo alle modifiche spaziali previste e agli elaborati pianificatori dettagliati. I LOD più elevati sono quindi da preferire nella fase di partecipazione, in quanto possono fornire un'impressione migliore del progetto di pianificazione.

Parole Chiave:
realtà aumentata, livello di dettaglio, pianificazione urbana, partecipazione digitale, valutazione

Evaluating Different Levels of Detail in AR for Enhancing Citizen Participation in Urban Planning

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1. Introduction

Digital technologies are now an integral part of urban planning (Batty, 2024; Christmann & Schinagl, 2023; Wilson & Twedwr-Jones, 2022). This becomes especially visible in the area of urban design, where the focus is on the digital design of built environments or spatial arrangements in cities (Al-Kodmany, 2002; Kikuchi et al., 2022; Othengrafen et al., 2023; Rohil & Ashok, 2022). New visualization tools such as Augmented Reality (AR) offer a great opportunity for urban planning, not only offering design methods, but also methods of presentation that form the basis for innovative participatory planning processes. Azuma (1997: 2) characterises the combination of reality with virtual elements, real-time interaction and the presentation of content in 3D as the three essential features of AR systems. Its usage has gained increasing attention in recent years in the building sector (El Asmar et al., 2021), as this technology offers the ability to bridge the gap between the digital and physical realms. AR therefore allows for the seamless integration of digital information, virtual elements/objects, such as 3D models, annotations, and data visualizations, into the user's view of the actual environment, providing a more intuitive and engaging way to experience and interact (Azuma, 1997; Kikuchi et al., 2022).

In the city of Lucerne (Switzerland), for example, an AR-supported participation process was initiated in September 2021 for the redesign of Bahnhofstrasse and Theaterplatz to involve the public more closely in the discussion and decision on the specific structural and spatial design proposals (Othengrafen et al., 2023: 59). Digital objects, small-scale interventions in the public space and design variants (including changes to the road layout, cycle paths, trees, benches and bicycle stands) were displayed on smartphones and tablets using a specially developed AR application, which could be used by the city's citizens as part of the participation process to gain an impression of the intended planning and design (Othengrafen et al., 2023: 59-60). The city of Vienna (Austria) took a similar approach to the redesign of Bernardgasse and developed the GLARA App, an AR-based application for citizen participation in the planning process (Höftberger et al., 2023: 1071-1072). This also allowed planning interventions and design variants to be viewed virtually and experienced live on site (Othengrafen et al., 2023: 58). In addition, the effects of a climate-friendly redesign with an increased proportion of green spaces and a reduced number of cars on the street were visualised by presenting climate data and temperature differences between the current state and the new planning variants (Höftberger et al., 2023: 1074; Othengrafen et al., 2023: 58-59).

These two but also further cases show that AR offers urban planners and stakeholders a more immersive and interactive way to engage with and understand urban design proposals in their daily work (Othengrafen et al., 2022, 12; Friesecke, 2020: 148). For example, AR can contribute to present the planning intentions and possible design variants more realistically, to support planners in the preparation of decision-making, or to collect specific data for the planning process (Alazzawi & Alsamer, 2024). Additionally, AR can increase the motivation of residents to participate in planning processes and to introduce new target groups such as young people to participate (Othengrafen et al., 2023: 61).

As further studies (Leu, 2021) have shown, AR can be used to capture the spatial effects of an intended project at different levels of detail (LOD) which is a key aspect for using AR in urban planning. LODs refers to the level of complexity and granularity with which virtual elements are represented, ranging from low-fidelity simplified models to highly detailed and realistic renderings. The selection and implementation of appropriate LOD can have a significant impact on the effectiveness of AR in engaging stakeholders and citizens, and in facilitating their understanding and participation in urban planning processes. Especially the incorporation of different LODs in the AR visualisations can be powerful in enabling the communication of different aspects of the intended plans and projects at appropriate levels of abstraction. However, it is unclear which LOD is most appropriate for digital participation of citizens to convey and communicate the planning conceptions in a clear way.

It is thus the aim of this paper to explore the potential benefits and challenges of AR and different LODs in urban planning processes. Therefore, we developed an AR App – as part of the 5G-CityVisAR research project (https://www.adesso-mobile.de/referenzen/5g-cityvisar/) – that augments 3D models as urban planning designs in situ and that could be tested with potential users as part of a fictitious planning project. We selected an area in central location in the city of Schwerte, 15km south-east of Dortmund in North Rhine-Westphalia (Germany) as use case for the AR App. The area shows a disorganised urban structure with partly unused areas and is suitable as a potential area for re-densification for internal development (Fig. 1). As the presentation of large-scale urban development designs using AR is only at the beginning of its development and only little research has been done so far on how and in what detail these designs should be used in participation processes, our paper contributes to the scientific discussion on the applicability, user-friendliness and added value of AR for planning procedures at the neighbourhood or district level.

Fig. 1 – Area in the city of Schwerte that is being considered for the use of AR as part of the research project as case study. The area shows a disorganised urban structure with partly unused areas. Source: TU Dortmund University - Uwe Grützner, 2024

2. Research Design and Methodological Approach

LOD in the Context of AR

In general, LOD is considered a 3D model's product description and is distinct from ideas about data quality like accuracy or spatial correctness (Cudzik et al., 2023). According to Biljecki et al. (2013), it is important to know what the LOD drives, how multiple LODs can be sorted or what the constraints and specifications for each LOD are about. In this sense, the LOD in CityGML differ with regard to the representation of buildings, roof forms, city furniture, vegetation objects or other specifications. For example, LOD 1 only shows the outlines of the planned buildings and thus simple building cubatures, while LOD 3 can then also include further details such as the shape and pitch of the roof, windows, balconies, etc. (Cudzik et al., 2023).

In this sense, Boos et al. (2023: 23) argue in their study that the LOD depends on the specific use of the 3D model in the planning process. In their view, no particular level of detail for the visualisation of a planned building is most appropriate for all purposes; on the contrary, different planning phases require different forms of visualisations (Boos et al., 2023: 23). It can therefore be assumed that a less detailed representation of models, designs and sketches (LOD 1) signals to users that they can make changes and additions so that this LOD could be used at a relatively early planning stage (Boos et al., 2023: 23; Klausener, 2012). However, the rather abstract way of representing urban structures and buildings also requires a lot of prior knowledge, so it is unclear to what extent LOD 1 really can improve communication with residents. Nevertheless, Boos et al. (2023: 23) further argue, that a detailed model (e.g. LOD 3) could be more appropriate in later planning phases to discuss planning details, design principles etc. before the construction finally starts. These assumptions need to be examined in the context of this article and on the basis of our own empirical findings.

Boos et al (2023: 23-24) see limitations in the use of AR in the overlapping of virtual objects in the AR application, i.e. when the representations are not displayed correctly, which can make it difficult for participants to distinguish between different LOD. One of the key challenges here is to create several representations by consistently using and managing their attributes (Cudzik et al., 2023). In addition, incorrect calibrations/scaling, inaccuracies and incorrect alignment of objects could have led to misjudgements by the participants. A good procedure needs to be developed here in order to be able to react to dynamic changes in the real environment when using AR.

The Development of the AR App and Definition of the LOD

In the run-up to the App development, established AR projects in the field of urban planning in German-speaking countries were analysed to derive useful functions and technical features for the intended AR application. That was the starting point for defining the technical specifications and requirements for our own App. We achieved this in several interaction rooms, a workshop concept used in software engineering (Book et al., 2016: 39) that enabled us to identify, consider and model dependencies, contradictions and gaps between technical requirements and urban planning issues at an early stage. At the same time, we developed two urban designs as fictitious planning scenarios for the project area, each including a spatial vision, the design of a master plan and a detailed design plan as well as the development of a digital 3D model (Reicher, 2017: 174-196) for later implementation in the App.

Since participation takes place in different planning phases and the contents or graphical representations of the concepts vary greatly, we have implemented the respective urban development plans and concepts in four different LODs in the AR App (LOD 1.1, LOD 2.1, LOD 3.1 and LOD 3.3) to test their usefulness or benefits as part of the participation process (Fig. 2-5). The graphic design of the drafts as 3D visualizations is limited to a largely neutral view with reduced representations, so that the evaluation of the depicted 3D models can focus particularly on the urban design as well as on the spatial dimensioning and placement. When implementing the 3D models into the real environment, the aim is to achieve the greatest possible accuracy so that the digital objects are precisely embedded in reality using AR. The basis for this is laid during georeferencing and the creation of the models in the CAD design software, in which the model is aligned in the area using referenced markers. But we did not consider high-resolution architectural visualizations to be useful as part of the planning participation process, since the specific design of a construction project – as in our fictitious case – is part of a downstream process and, in particular, encompasses the range of services provided by architects or civil engineers. On the other hand, the aspects that are to be conveyed via representations based on urban land-use planning are relevant to the planning process.

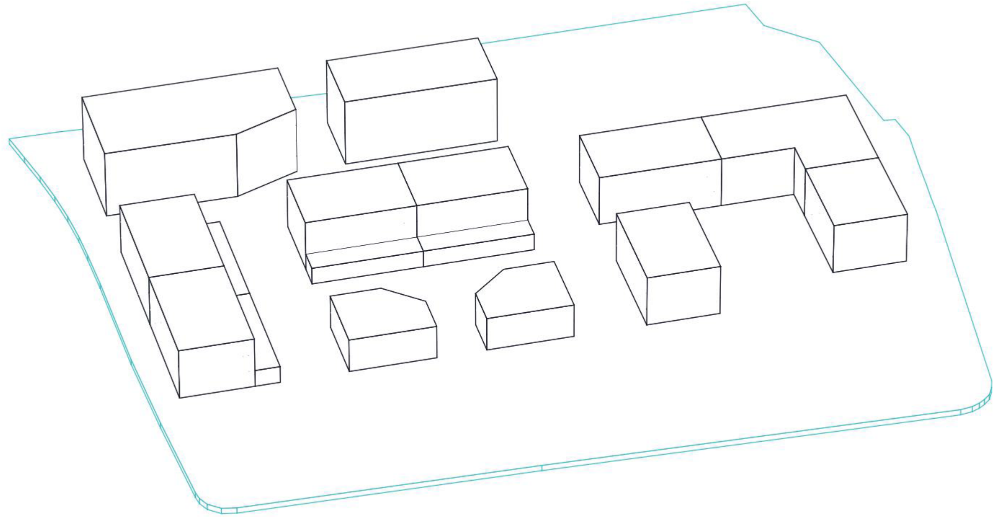


Fig. 2 - Representation of an urban planning design as 3D model in LOD 1.1 for integration in the AR App. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, 2024.

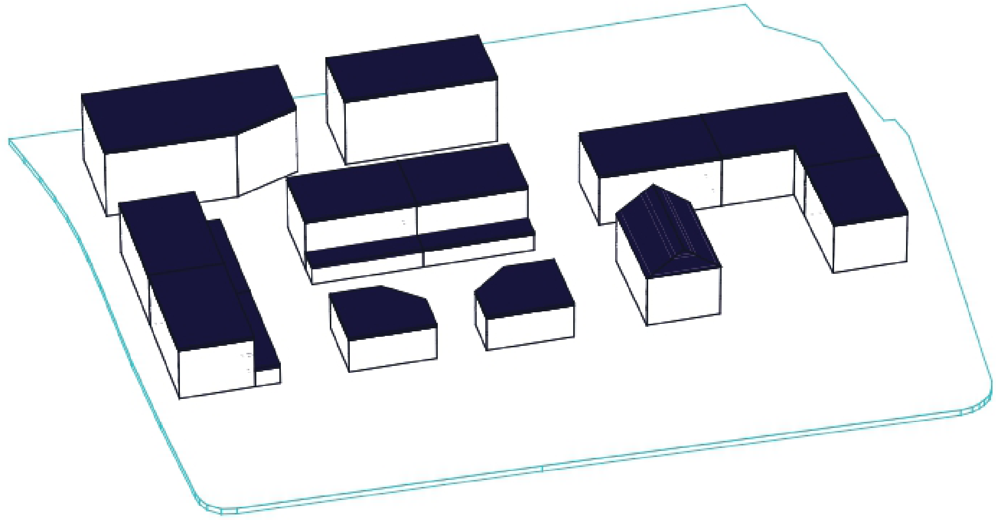


Fig. 3 - Representation of an urban planning design as 3D model in LOD 2.1 for integration in the AR App. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, 2024.

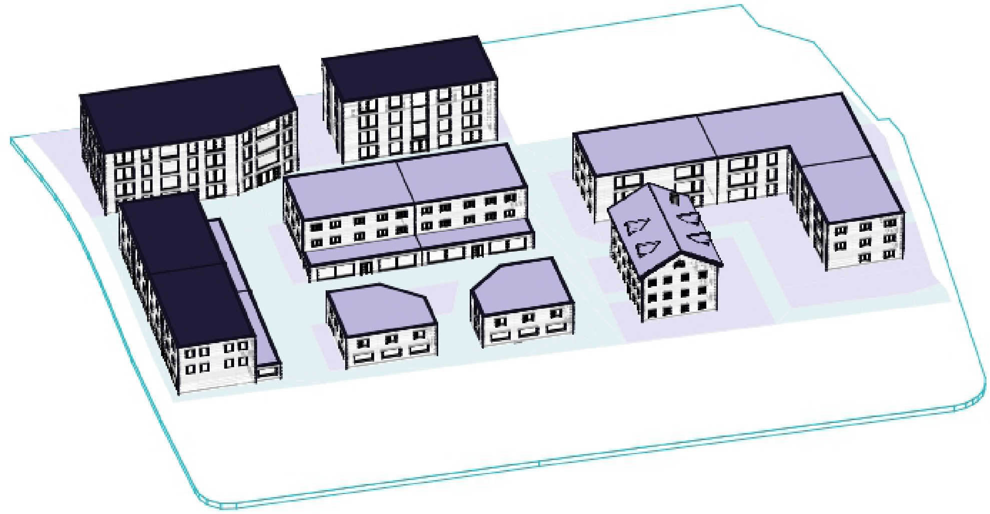


Fig. 4 - Representation of an urban planning design as 3D model in LOD 3.1 for integration in the AR App. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, 2024.

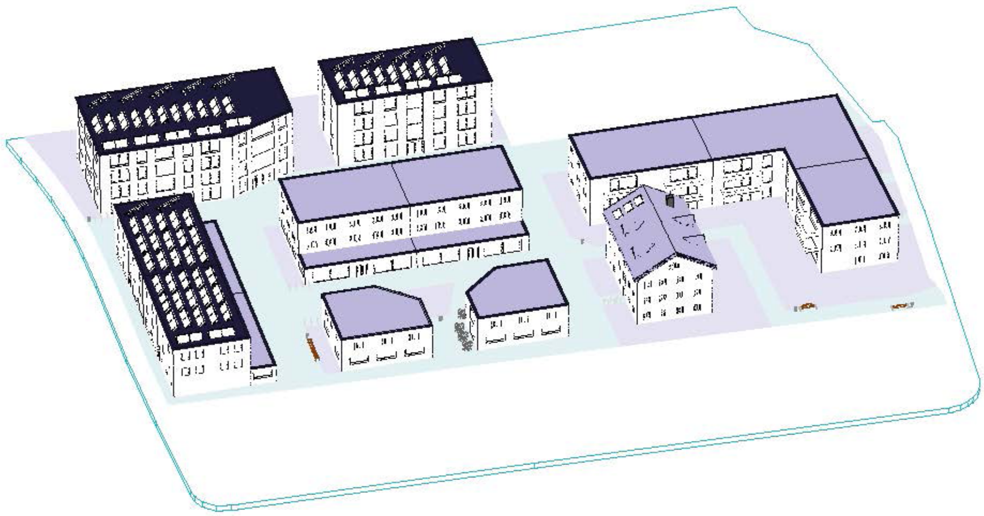


Fig. 5 - Representation of an urban planning design as 3D model in LOD 3.3 for integration in the AR App. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, 2024.

Testing and Evaluating the AR App in Practice

The developed AR App was tested with administrative staff and representatives of political committees of the city of Schwerte in February 2024 (Fig. 6, Fig. 7). The plans and concepts were first presented in a conventional way as analogue 2D plans before all participants tested the AR App in the planning area. For this purpose, the participants were provided with various end devices (smartphones and tablets from different manufacturers and operating systems) with which they could view the two plans and 3D-models with the different LODs 'live' in the planning area and embedded in the surrounding buildings. The app makes it possible to explore the planning area, whereby the digital models and objects are embedded in the real environment. Real elements like existing buildings and green spaces that have not undergone any design intervention remain visible. To access the models the participants had to scan a QR code with the App in the planning area; this gave all participants direct and immediate access to the AR models, ensuring intuitive and fast operation and quick access to the AR App. After the workshop and the test of the AR App, the participants anonymously evaluated the App. For this purpose, 35 participants completed an online evaluation form to evaluate the participation format, the added value of AR for participation processes, the design presentations including the LOD, and the usability of the App. The majority of 28 people (80%) of all participants stated that they already had extensive knowledge in the field of urban planning. In contrast, however, there is less experience in dealing with AR applications. Only 12 persons, a third of all participants, stated that they had already actively used AR; 23 persons said they had not. The following chapter will present the selected results of this survey as well as our observations during the AR App test.

Fig. 6 – In situ visualisation of urban designs as 3D model in LOD 1.1. and LOD 3.3. via augmented reality in the City of Schwerte. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, Luisa Nagel, 2024.

Fig. 7 – Test and evaluation of the AR App by participants directly in the area of the urban planning designs. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, Luisa Nagel, 2024.

3. Evaluation of Urban Planning Principles and Different LOD in the AR App

The practical test of the AR App shows that the participants rate the App as a more vivid approach or tool than traditional and abstract 2D urban plans or concepts. The fact that the participants are able to view and 'experience' the spatial structure, the building hights and distance spaces in the App is particularly appreciated by the participants as an added value. The majority of respondents believe that digital visualization via AR can help to describe the plan concept to others, in particular non-experts or not-involved persons. Seven participants (20%) 'completely agree' with the corresponding statement, 15 participants (42.9%) tend to agree or 'rather agree'. Only 13 participants 'rather disagree' with the statement. In contrast, the statement "I see no advantages in the AR App compared to the presentation of traditional plans in 2D" is clearly rejected by a vast majority of the participants. In summary, the test persons regard the use of AR in participation processes as a valuable or profitable approach that improves participation in principle. This is also reflected in the assessment of the thesis "AR is appropriate for innovating participation in the future". Here, 23 participants (65.7%) 'fully agree', 10 participants (28.6%) tend to agree and only 2 participants (5.7%) 'rather disagree'. We can conclude here that the AR App enables a more serious consideration of plans and concepts, since the user is in situ in the planning area and receives a realistic impression of plans and concepts via the App and the urban designs presented here in front of the surrounding buildings and infrastructures. This provides a strong basis for public discussions in participation processes, as all participants have a better idea of and similar information on the spatial dimensions and effects through the visualization of the plans and their embedding in the plan environment; participation can thus take place 'at eye level' between all stakeholders involved in the planning process.

The evaluation further shows that relevant urban planning elements, such as building hight, building width or distant spaces, are assessed differently by users in the digital visualisations in AR models. The vast majority of respondents were, compared to the presentation and interpretation of the 2D plans, better able to assess the buil-

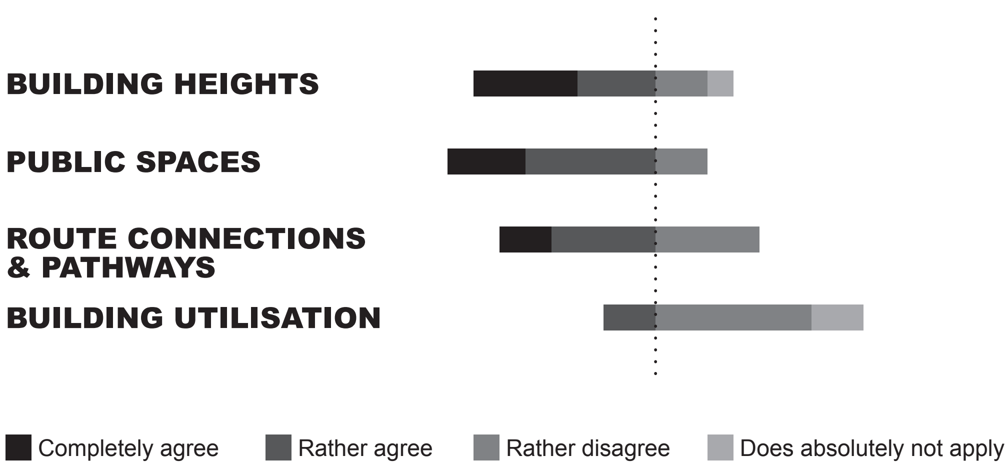
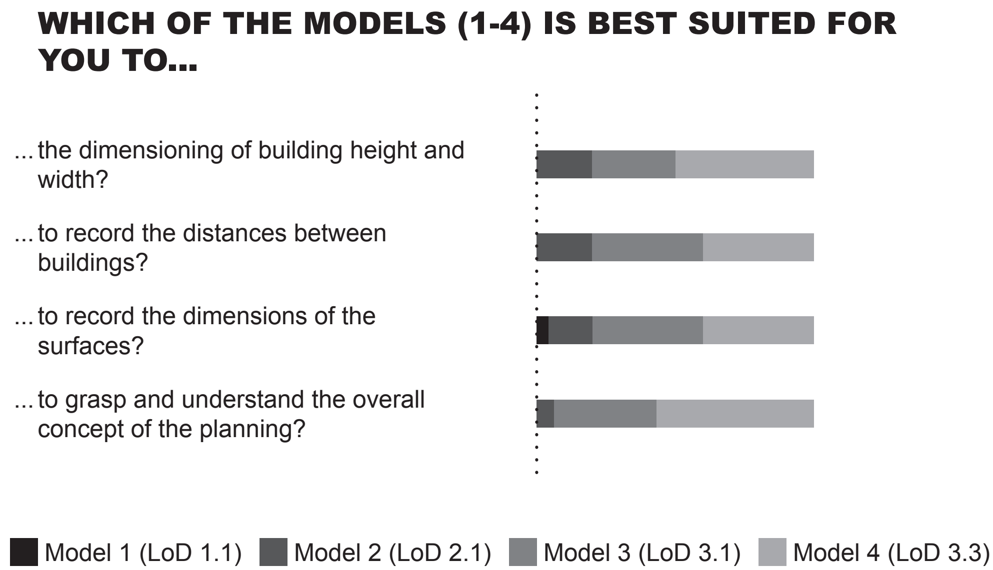


Fig. 8 – Statistical evaluation of the perception of urban planning aspects via the presentation of digital visualisation in AR. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, 2024.

Fig. 9 – Statistical evaluation of the assessment of different levels of detail in AR with regard to specific urban planning aspects. Source: TU Dortmund University - Department of Spatial Planning - Research Group of Urban and Regional Planning, 2024.



ding heights in the AR App, and to understand the dimensions of the intended plan in relation to the surrounding structure (Fig. 8): 15 participants (42.9%) 'completely agree', and a further 11 (31.4%) 'rather agree' with the corresponding statement. Seven participants (20.0 %) 'rather disagree' and only two participants (5.7 %) 'do absolutley not apply' that the perception of building heights can be better perceived via the AR visualisation. The presentation and perception of public spaces in the planning areas via the AR models was rated similarly, with 11 participants (31.4%) 'completely agreeing' and 16 (45.7%) 'rather agreeing'. However, 8 participants (22.9%) 'rather disagree' that the AR App increases the perception of public spaces. Here, some participants also raised complaints about the ways in which trees and vegetation were depicted in the AR App, as they felt that these – at least in the current presentation – had only little effects on communicating the plan concept. The assessment of the perception of route connections and pathways in the plan concept shows more ambivalent results. Here, each 15 participants (each 42.9%) 'rather agree' or 'rather disagree' that route connections can be communicated and assessed well through the AR App. Only 5 participants (14.3%) stated that route connections can be assessed well or better through the visualisation in AR. The critical assessment is understandable as streets, sidewalks, etc. were not comprehensively depicted in the AR App; the focus of the presentations was on the buildings, which meant that the route connections and pathways were rather difficult to follow. According to the participants, it was also difficult to imagine the intended building utilisation via the AR model (Fig. 8): none of the participants 'completely agreed', while only 8 (22.9%) 'rather agree'. The vast majority of 21 participants (60.0%) 'rather disagree' and further 6 participants (17.1%) 'do absolutley not apply' with the statement that 'AR models made it possible to assess the building utilisation well'. Here, the plain colouring of the 3D models was also criticised; a differentiated colouring of the visualisation and objects could have increased the understanding of certain types of use.

4. Conclusions

The testing and evaluation of the AR App developed by us prove the added value of AR in participatory planning processes and confirm that the immersive display of 3D models on a planning area can improve the understanding of planned projects and infrastructures. AR thus has the potential to become an integral part of urban planning processes to participate citizens and other stakeholders in planning processes. It allows planners to communicate planning ideas and principles, details on building hights, public spaces etc., since AR offers new forms of visualisation that enables a more realistic presentation of plans and concepts. Additionally, the interactive nature of AR makes it possible to make a concept tangible and experienceable directly on site. This enables planning to involve citizens in a more self-determined way and to promote collaborative decision-making at 'eye level'.

From an urban planning perspective, the structural elements such as the dimensions and height of buildings and their positions in the urban context are particularly relevant in the visualization. This again emphasises the importances of 3D models with higher LODs for adequate visualisation in AR. The focus here is less on detailed textures, such as the material and composition of the walls, but more on the cubature. This kind of presentation or visualization allows users to imagine the planning dimensions, i.e. the planning ideas and principles and their impacts on the surrounding area. However, the AR visualizations can also trigger concrete ideas of reality in individual users that have not yet been formally decided upon. This could potentially lead to disappointment among stakeholders if the implementation later deviates from the visualizations.

We argue, similar to Boos et al. (2023), that AR and the use of different LOD depends largely on the planning phase in which public participation is to be carried out. Our results suggest that more advanced and particularly more conceptual phases seem to be more appropriate for the use of AR, i.e. planning phases in which planners have already created initial concepts/drafts which can be discussed with the public. This is because in early planning phases, planning considerations may not yet be fully developed, and the population may not be able to interpret them appropriately, also due to a lack of expertise. It is possible to integrate a different LOD, which users can switch between to select an appropriate presentation for their own purpose. The idea of using different LODs in different planning phases seems logical from a theoretical perspective; however, it is important to consider whether the effort involved in developing an AR model including different LODs with the generated output is in line with a reasonable cost-benefit ratio and can provide additional output for planners. Nevertheless, AR can offer beneficial results in early planning stages as various, and occasionally conflicting, alternatives and solutions can be discussed and compared with various stakeholders involved in the planning process (Othengrafen et al. 2023: 61). However, in more detailed phases, the use of

AR models would unquestionably contribute to strengthen the population's sense of ownership of a plan concept and thus obtain good input for further planning and possible changes. An essential factor here is that the municipal administrative authorities are open to use innovative tools such as AR and to integrate them as elements into their planning routines.

As our evaluation further indicates, many users find it rather difficult to reproduce certain planning details or representation, e.g. the classification of the building use. In addition to an improved presentation of the plan contents in the AR App, further explanations of the plans are thus important as planning details are often not intuitively understandable for users without explanations and justifications. If the AR App should be used by citizens independently, explanations in the form of audio, text and images are obligatory, e.g. through annotations. This may include information on building use, basic ideas and considerations on the urban development concept, but also explanations or visualisations of the contents and restrictions of planning regulations. If this information is presented in a way that is appropriate for laypeople, it represents added value for information on a planning concept and makes participation more comprehensible. This again demonstrates the significance or weight of higher LODs, as plans and details of individual plans can be displayed more transparently here and are therefore easier for laypeople to understand. A further improvement of the AR App could be to virtually delete buildings and objects, which exist in the planning area but are no longer relevant for the future development, from the virtual presentation or visualisation (diminished reality). As it is often difficult for citizens and other stakeholders to imagine what an area looks like without existing buildings and objects, diminished reality could contribute to improve that.

We are further convinced that higher LODs can play a prominent role when AR Apps are linked with artificial intelligence (AI) systems (Othengrafen et al. 2023: 62). AI systems enable urban planners and decision-makers to tie AR and other 'visual tools in with much more detailed, longitudinal, massive performance data sets to support comprehensive and useful forms of visual analytics' (Lock et al. 2019). For example, digital twins can combine different data sets such as statistical data (population etc.), georeferenced data (eg. potential roof sites for solar energy etc.), or real-time data (e. g., traffic flows, energy consumption) which can build the basis for developing 'what happens if…' scenarios in AR visualisations to illustrate the impact of concrete actions on climate protection or adaptation goals. Here, AR together with AI systems, can help analysing and evaluating sustainable and less sustainable development options throughout the entire planning process (from the development of alternatives to the concretization of partial solutions to design issues at the building level). Additionally, AR can contribute to increase the transparency and acceptance of climate mitigation and adaptation options among private actors and to improve the decision-making basis for politicians and planners (Othengrafen et al. 2023: 62). Here, too, it can be assumed that AR visualizations with higher LODs are more effective than AR models with low LODs.

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