

BIM-Based Public Participation: Insights and Lessons Learned from a Case Study

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Abstract

Public participation is critical to the success of construction projects as it enables citizens to influence and engage in planning processes. Traditional participation methods often rely on two-dimensional technical plans, which are frequently perceived as difficult to understand, particularly by non-experts. In recent years, digital visualization techniques, especially 3D models, have emerged as promising alternatives. These approaches promise to enhance communication among stakeholders and deepen engagement by offering clearer and more comprehensible representations of construction projects.

This paper explores how public participation based on 3D BIM model data can be implemented and examines the user experiences associated with such an approach. The concept is built on a 3D BIM model-based participation platform integrated with a Common Data Environment (CDE), which serves as the source for three different model variants.

A prototype of the participation platform was tested in the context of public involvement for the redesign of a mobility space in a German city. Citizens were therefore invited to interact with the various model variants and actively participate in the process.

Findings from this initiative demonstrate that guided textual information with 3D visuals enhances citizens' comprehension of the project. Users particularly valued the 3D models for enhancing their understanding, while expressing a preference for rather realistic models, even if they are more complex. In summary, the results suggest that BIM models can significantly enhance public participation by improving comprehension and engagement, ultimately contributing to social sustainability.

Keywords

Building Information Modeling (BIM), public participation, 3D visualization, e-participation, participatory planning, Scrolltelling, Common Data Environment (CDE), social sustainability

1 Introduction

Public participation plays a crucial role in the success of construction projects [1], as it enables citizens to exert influence and contribute to the decision-making processes of projects planned within their communities [2]. Inadequate integration of the public in planning processes can have significant consequences, including protests, legal disputes, and delays in project timelines. These issues often result in construction projects failing to meet budgetary and scheduling targets [3].

Understandable visualizations are considered fundamental for successful public participation [4]. According to King et al. (1989), visualizations are the only common language that all stakeholders, both technical and non-technical, can refer to [5].

Currently, primarily two-dimensional technical plans, floor plans, sections, and views are provided as supporting visualizations of the project to the public [3]. Consequently, technical drawings represent the most commonly used method for visualizing construction projects [2].

However, there is a consensus that these are generally difficult to understand, especially for stakeholders with little or no experience in interpreting maps [1; 3; 6]. Consequently, such forms of representation can be considered outdated and ineffective in the context of public participation.

With the increasing digitization in recent years, methods have increasingly been employed that promise improved communication and representation of information [2]. These novel visualization methods are often closely linked to digital participation formats, collectively referred to as e-participation measures. At the core of these measures are Information and Communication Technologies (ICT), which aim to facilitate and make the exchange between stakeholders more efficient [7].

Numerous studies can be found that examine the role of digital visualization formats and their impact on public understanding and participation.

The study by Skaaland and Pitera (2021) investigated the use of digital visualization techniques in the context of public participation in infrastructure projects in Norway. A survey was conducted among professional users in the Norwegian infrastructure sector, comparing various visualization techniques to examine their impact on public understanding. The study identified that digital visualization models led to a statistically significant increase in public understanding and engagement compared to traditional visualization models [2].

In another study by Onyambu et al. (2018), the use of 3D visualizations in the context of digital public participation in Kenya was examined. Questionnaires were sent to planners to assess the user-friendliness of 3D visualizations. The study concluded that the use of 3D visualizations has the potential to improve both the quality and quantity of public participation. Consequently, 3D visualizations are able to promote the involvement of stakeholders and enhance their understanding of the proposed plans [1].

This finding aligns with the statement by Milosz, who further emphasizes that digital 3D models allow non-experts to have more control over what they want to see, as opposed to what planners want to show them [8].

The research project VISB+ examined the contribution of visualizations to improved communication of construction plans. Various visualization approaches were analyzed within the study, with interactive visualizations being particularly highlighted for their added value. Furthermore, the study emphasizes the potential benefits of applying Building Information Modeling (BIM) in the context of public participation [4].

BIM represents a methodology that has seen increasing adoption in the construction industry since the early 21st century. Fundamentally, this approach relies on the use of digital building models and the semantic information within these models throughout the entire lifecycle of a building [9]. Buildings are represented as three-dimensional models, with each component being detailed and digitally depicted [4].

By using BIM models, different planning variants can be visualized and made tangible in the real environment [3]. Furthermore, these models allow for the interactive integration of additional layers of information, such as noise propagation or shading effects. This could significantly simplify communication in the context of public participation and contribute to greater transparency, as well as enhance the social sustainability of construction projects [3].

Despite this potential, the VISB+ study concludes that the use and research related to the application of BIM models for public participation is still limited. In particular, there is a lack of comprehensive studies on how these models can be effectively integrated into

participatory processes to foster broad acceptance and understanding among non-technical stakeholders. Therefore, further research and development efforts are necessary to explore the application of BIM in the context of public participation.

The aim of this study is to examine the use of BIM model data in the context of public participation and to collect user experiences in this regard.

The study is part of the research project BIM4People, funded by the Federal Ministry for Digital and Transport in Germany. As part of this project, a digital participation platform is being developed, which presents BIM model data and will be tested and optimized through several real-world use cases.

This study provides a comprehensive overview of the approach and findings from a case study of a BIM-based participation platform. The case study is situated in a German city with approximately 100,000 inhabitants, representing a voluntary initiative to explore innovative means of involving the public in urban development projects.

The underlying concept of BIM-based participation is detailed in the following second chapter. Additionally, the study area, the model variants, and the opportunities for public participation are described. In the third chapter, the empirical study that accompanied this case study is presented. The aim of the empirical study is to identify the user experience of participants in relation to the BIM-based participation platform. The study aims to gather insights into how digital 3D models can be effectively integrated into public participation processes to enhance transparency, foster acceptance of construction projects, and explore public perceptions of these models. This chapter includes the specific research topics as well as the corresponding findings. The final chapter of this study provides a discussion and conclusion regarding the case study of public participation based on BIM model data.

2 The concept of BIM-based public participation

At the core of BIM-based public participation are two key software products. On one hand, there is a Common Data Environment (CDE), which serves as the central information source. A CDE is used to collect, manage, and disseminate relevant information related to a specific project [10].

In the study discussed below, three model variants were developed collaboratively by the city and the planning office as part of a BIM-based planning process. These models were created using authoring software and subsequently uploaded to the CDE in Industry Foundation Classes (IFC) format. This approach facilitated a centralized storage system, enabling collaboration and data exchange among the different

stakeholders.

In this use case, the IFC model was subsequently integrated into the city model developed during the urban planning concept phase. The city model itself was also available as an IFC file.

Since a CDE is primarily designed as a planning tool for professionals, a second software product, a digital participation platform, is developed and subsequently used for a case study. This platform enables the public to view the model variants through an IFC viewer and access the associated information, allowing them to actively participate in the planning process.

In order to display the IFC models on the platform, xeokit, an IFC viewer which allows open-source 3D graphics formats to be displayed in the browser [11], was used.

The study described below incorporates a Google Maps layer into the BIM-based platform as an additional feature for spatial orientation. This integration highlights the geographical context of the project, displaying its location in relation to the existing urban structures. The familiar Google Maps interface is intended to enhance users' comprehension of the project's spatial context by offering a clear and intuitive visualization of the area in which the project is situated.

The concept of BIM-based participation, which is based on the research findings of Matthei et al. (2024) [12], is summarized in the following figure.

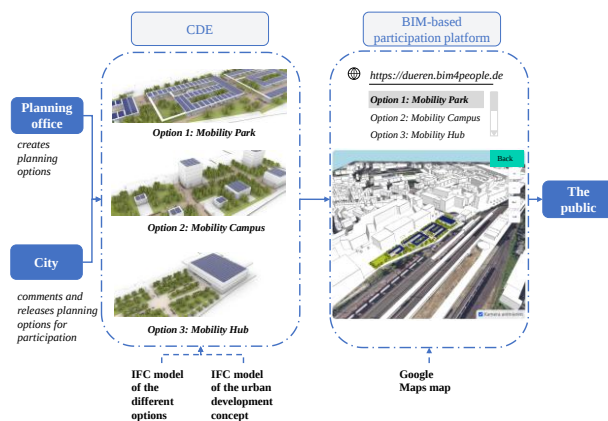


Figure 1. Concept of the BIM-based public participation

2.1 Study area

The study area for the BIM-based public participation concept is located in Düren, a city of approximately 100,000 residents, situated between Aachen and Cologne. Due to its location in a densely populated state and between two major cities, Düren has a high number of commuters. The city is also significantly impacted by the structural transformation from the coal phase-out, with job losses, weakening supply industries, and declining retail purchasing power [13].

An urban development project is planned along Düren's main train station, where a new 150,000 m² district will be created. A specific area within this project will focus on developing and evaluating innovative mobility solutions. In this area, the BIM-based public participation using three model variants is located.

2.2 Model Variants and Participation Opportunities

Three model variants were developed early in the BIM-based planning process to be assessed during the public participation phase. These are preliminary drafts, not detailed plans, aimed at gathering public input on needs and preferences. Option 1 (Mobility Park) emphasizes mobility services, open spaces, parking, green areas, and solar roofs. Option 2 (Mobility Campus) features modern parking towers with automated parking and sustainable materials. Option 3 (Mobility Hub) focuses on a compact building with integrated uses.

Each option is supplemented with brief textual descriptions on the BIM-based participation platform, providing citizens with a clearer overview of the content. The presentation of the variants is done in the format of "scrollytelling," which serves as a promising tool for conveying complex information in an understandable way [14]. In scrollytelling, participants navigate from one story point to the next by scrolling. Each story point represents specific locations or situations within the model that have been pre-selected to guide users through the respective variant in a structured manner. These story points are accompanied by explanatory texts that provide additional information about the displayed scenes, deepening the users' understanding of the content.

The model is automatically aligned with the location described in the text, establishing a strong connection between the visual content and the accompanying texts. This methodical linkage aims to enhance the understanding of the complex spatial and urban planning relationships. In addition to the guided presentation, citizens have the opportunity to freely explore the model variants. Participants can switch between views, zoom in, and rotate the 3D model, allowing for a more personalized and comprehensive impression of the planning variants. Public participation takes place by allowing citizens to view the model variants, create their own contributions, and to read contributions from other users, which they can also agree with. When submitting a contribution, users have the option to associate it with one of the three model variants and place a marker at a specific location within the model (see figure 2). This allows concerns to be linked to a precise spatial allocation, facilitating clearer understanding of the issues raised. Additionally, contributions can be categorized by topic to facilitate targeted processing of concerns by the city administration.

Figure 2. Participation opportunity on the BIM-based participation platform

3 Empirical study

3.1 Proceedings

As part of the BIM-based public participation process, 600 flyers were distributed within the study area, supplemented by announcements in local newspapers, on the city's website, and through social media channels. A QR code and a direct link to the participation platform were provided to facilitate access and encourage public engagement. The public participation period was open from October 24, 2024, to November 17, 2024.

To capture detailed user experiences, a survey was integrated directly into the BIM-based participation platform. Participants were invited to take the survey on the final page of the platform after reviewing the different model variants. Additionally, users who submitted a contribution were also prompted to complete the survey. This methodology aimed to gather a broad and representative sample by encouraging both passive and active users to participate.

The survey is divided into two sections. The first part collects demographic and socio-economic information about the participants, including gender and age. In addition, participants are asked about their relationship to the particular city, e.g. whether they are residents or commuters. The section also gathers information on their previous experiences with public participation in general.

The second part of the survey aims to gain detailed insights into the user experience of participants with the BIM-based participation platform. It focuses on experiences related to navigation and spatial orientation

within the 3D models. Additionally, the usefulness of various platform functionalities is examined, including the georeferenced placement of contributions, the guided presentation of content through scrolling on the platform, and the categorization of contributions. Another key focus is on how the 3D representations help participants better understand the project and how useful the ability to compare different project variants using a 3D model is. The second part of the survey is conducted through multiple-choice questions on a 5-point Likert scale.

3.2 Findings

The following subchapter present the key findings from the conducted BIM-based public participation process. First, general observations are presented, followed by user experiences based on the insights gathered from the survey placed on the platform.

3.2.1 General findings

The BIM-based participation platform had 593 unique users, with an average visit duration of 3 minutes and 39 seconds. Of these, 364 users accessed the platform via mobile devices (61%), spending an average of 2 minutes and 12 seconds, while 229 users accessed it via desktop, spending an average of 4 minutes and 40 seconds.

Among the 593 visitors, 76 individuals were returning users, indicating that they accessed the platform multiple times. A total of 24 contributions were submitted on the platform, 16 of which included a direct link to the respective variant referenced in the comment. The first variant was linked six times, making it the most frequently referenced option. Furthermore, in three instances, contributions were linked to specific locations within the model.

An analysis of the thematic categorization of contributions revealed that in 71% of cases, the assigned topic accurately matched the content of the submission.

3.2.2 User experience

A total of 23 individuals participated in the survey aimed at identifying user experiences. Of these, 21 respondents completed at least 80% of the survey. The following section exclusively presents the findings derived from these 21 participants.

The participant background reveals that 86% had never participated in public engagement activities before. Regarding gender, 48% identified as male, 43% as female, and two participants chose not to disclose their gender. In terms of their relationship to Düren, 41% lived there, 18% worked in the city, and 27% commuted for work. The age distribution was balanced across 18-64 years, with a slight prominence in the 25-34 age group. No participants were under 18 or over 64, and one participant did not provide their age (see table 1).

Table 1 Age Distribution of Survey Participants

Age	Number
<18	0
18-24	4
25-34	5
35-44	4
45-54	3
55-64	4
>64	0
n/a	1

The evaluation of user experiences with spatial orientation and navigation in the 3D model shows that 33.33% of respondents found orientation to be "neither easy nor complicated," while 20% experienced some difficulty, and 15% found it "very easy." Regarding navigation, 38.10% rated it as "very easy," 23.81% found it "somewhat difficult," 14.29% considered it "somewhat easy," and another 14.29% viewed it as "neither easy nor difficult." One participant, aged 55–64, found navigation "very difficult." A detailed representation of these results is provided in the following figure.

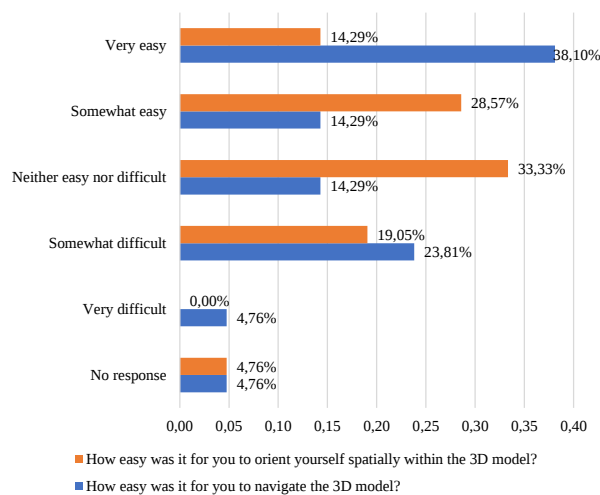


Figure 3. User experiences regarding orientation and navigation in relation to the 3D model

The investigation of functions on the BIM-based participation platform revealed that the guided presentation of information (scrollytelling) with textual and 3D model elements was seen as helpful by most participants. Over two-thirds rated it as "very helpful" (47.62%) or "somewhat helpful" (19.05%), with 14.29% neutral. The ability to assign contributions to specific locations was considered "somewhat helpful" by 35% of respondents, with an equal number providing no answer. About 15% found it "very helpful," and 10% neutral. Categorizing contributions by theme was mostly rated as "somewhat helpful" (30%) or "very helpful" (25%), while 15% were neutral and 15% found it "somewhat unhelpful".

Regarding 3D visualization, 90% of participants said it somewhat improved their understanding, with 45% rating it "very helpful" and 45% "somewhat helpful." The comparison function of different variants using the 3D model was rated positively, with 50% finding it "very helpful" and 33.33% "somewhat helpful." A detailed overview of the evaluation is shown in the following figure.

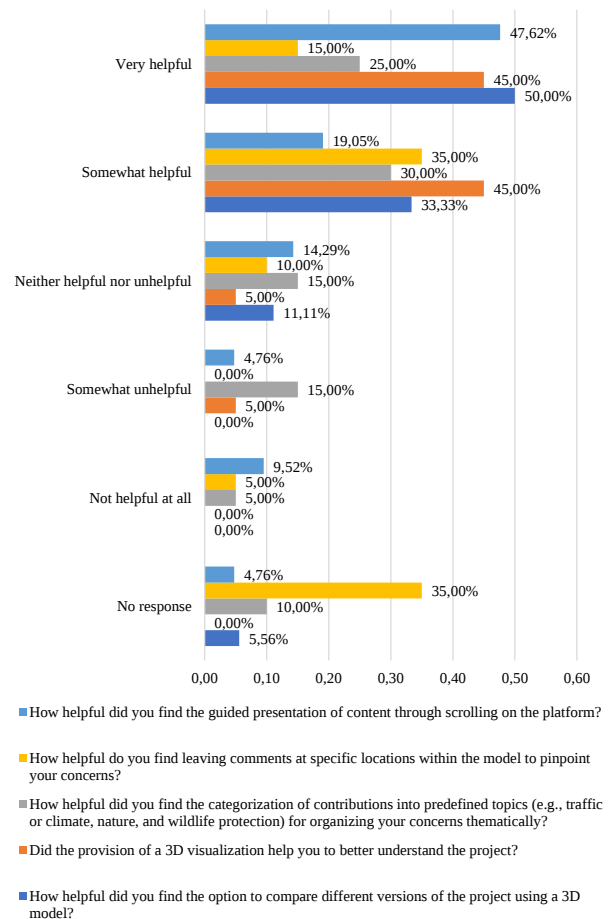


Figure 4. Usefulness of different functions

The majority of respondents preferred more realistic 3D models, even at the cost of increased complexity. About 17% favored a very realistic model, despite potential complexity, while 39% preferred a realistic model that was somewhat complex. One-third sought a balance between realism and simplicity, and only 5.56% desired a very simple, minimalistic model with little realism. No participants preferred a simple, unrealistic model. Detailed results are shown in the following figure.

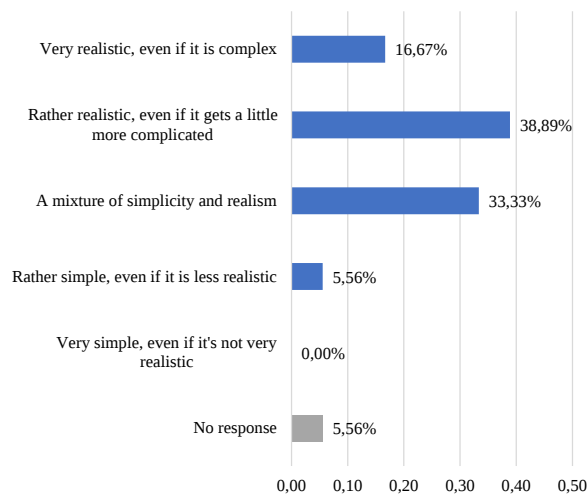


Figure 5. Respondents' 3D model detail and realism preferences

4 Discussion and Conclusion

4.1 Discussion

This case study of BIM-based public participation shows that 63% of users accessed the platform via mobile devices. However, desktop users spent more than twice as long on the platform, suggesting that while mobile devices are convenient, desktops offer a better experience for in-depth engagement, likely due to larger screens and easier navigation of complex 3D content.

Although the platform recorded a total of 593 different visitors and was available to the public for 24 days, only 24 contributions were made. This low level of participation may be due to the need to register by email when creating contributions and the mandatory public visibility of these. Low-threshold access could therefore significantly increase the willingness to participate in the future. However, the possibility of low-threshold participation harbors the risk that people will participate without having a deeper connection to the topic and without being directly affected by the measures under discussion [15]. The phenomenon of “slacktivism” or “clicktivism” can occur in this context. This term describes a form of digital participation in which people get involved through simple, often situational actions such as liking, sharing or commenting, often without deep engagement or direct personal impact [16]. The result would be a distorted participation result. Another reason for the low participation level may be due to the high information density of the platform, which could have overwhelmed users and hindered active engagement.

The active linking of contributions to the model variants was carried out for the majority of posts (16 out of 24). This indicates that the majority of users consider the option of linking their concerns directly to specific

model variants to be valuable and useful. In three cases, contributions were linked to specific model locations, suggesting the function was useful to some participants.

A common problem in public participation is the lack of representation: The same, particularly committed citizens often take part, which can lead to a distorted picture of the opinions and interests of the population. Only a specific, actively engaged group participates regularly, while the majority hardly uses the opportunities for participation. As a result, the population structure often remains incompletely represented and the results of participation do not necessarily reflect the entirety of those affected [17].

The results of this study, however, present a different picture: A large majority of participants (86%) reported that they had never previously participated in a public engagement process. This high proportion of first-time participants suggests that the digital participation platform was successful in reaching individuals who would otherwise not engage in traditional participation opportunities. Additionally, the age data from the survey indicates a broad distribution of participants. The age groups between 18 and 64 years are almost evenly represented, with a slight concentration in the 25–34-year-old category. This suggests that the platform also appeals to younger adults, a group that is often underrepresented in traditional forms of public participation [18].

The balanced gender distribution and the presence of both residents and commuters among participants suggest that the platform successfully appeals to a diverse user group. These findings indicate that digital participation platforms can reach a broader and more varied audience than traditional formats.

The results regarding the analysis of user experiences of spatial orientation and navigation in the 3D model show mixed experiences. In connection with orientation in the 3D model, around a third of respondents felt that orientation in the model was neutral, which indicates that the 3D model is functional in terms of orientation, but not particularly intuitive for many. This leaves room for optimization in connection with orientation support within 3D models. If necessary, additional introductions or tutorials could help to promote orientation within 3D models for citizens.

The majority of respondents found navigation within the 3D model “very easy,” suggesting that the interactive controls are well-implemented and intuitive. This may be due to the increasing accessibility of immersive technologies, familiarizing more people with 3D models [19]. However, about a quarter of participants found navigation “rather difficult,” indicating potential challenges related to varying technical skills or devices.

The conclusions drawn from the analysis of the various functions of the BIM-based participation

platform show that the platform is perceived as helpful and user-friendly overall. The guided presentation of information (scrollytelling), which consists of textual and 3D model elements, was rated particularly positively. Over two thirds of participants found this function helpful, which indicates that clear and structured information transfer in conjunction with interactive visual elements promotes user understanding.

A large proportion of respondents also found it helpful to locate contributions at specific points in the model, which underlines the importance of the spatial allocation of a contribution in the context of participation. Nevertheless, there was a considerable number of participants (35%) who did not provide any information on this, which could indicate that this option was not sufficiently pointed out or that it is still considered less relevant at such an early planning stage. The categorization of contributions according to thematic categories was predominantly seen as helpful. This shows that structuring contributions thematically allows for a better overview and targeted discussion of specific aspects of a project. However, some respondents found this function less helpful, which may indicate that an even finer adjustment of the categories or additional filter options could be useful. The provision of 3D visualization was rated as helpful by almost all participants, confirming that visual representations of complex projects significantly improve understanding. In particular, the ability to compare different variants of the project in the 3D model was found to be extremely helpful by the majority of users. This shows that the visual comparison of project variants, in addition to the textual comparison, is considered valuable by users and can contribute to a better understanding of the project.

Several conclusions can be drawn from the respondents' preferences regarding the level of detail and realism of 3D models: Firstly, there is a high demand for realistic representations. The majority of respondents prefer realistic 3D models, even if this is associated with increased complexity. This indicates that a detailed and realistic visualization is perceived as more important for the understanding and acceptance of the project than a simplified representation. Furthermore, there is an acceptance of complexity for better information content. The willingness to prefer more complex models shows that users value detailed information and are prepared to accept greater complexity in favor of better understanding. This speaks in favor of using models that reproduce details as accurately as possible. Regardless of this, a need for balance can be seen among some users. Around a third of respondents prefer a balance between realism and complexity, which indicates different user needs and abilities. In addition, there is a low demand for simple models. This is reflected in the very low preference for simple or highly abstracted models.

4.2 Conclusion

Digital transformation, particularly through Building Information Modeling (BIM), is enhancing infrastructure planning and public participation. BIM enables three-dimensional representations, improving transparency and comprehensibility compared to traditional visualizations, potentially fostering more intensive citizen engagement.

As part of this study, an approach for BIM-based public participation was developed that makes it possible to present BIM model variants located in a CDE to the public using a digital participation platform. As part of a case study in the course of redesigning a mobility space in a German city, initial empirical values were collected in order to evaluate the applicability and user-friendliness of a participation platform based on 3D BIM model data.

The study aimed to understand user perceptions of the platform and identify challenges and opportunities in interacting with 3D visualizations and other features.

The BIM-based public participation process has shown that guided information transfer (scrollytelling) in conjunction with interactive visual elements can be considered helpful. Citizens consider the possibility of seeing the project in 3D and comparing variants in this way to be helpful for their understanding of the project. The option of linking contributions with different model variants was frequently used in this context.

The evaluation of navigation in the 3D model is predominantly positive, which suggests that it is generally easy to use. Orientation in the 3D model also tended to be rated positively, although some users perceived this as "rather difficult". This indicates a need for optimization in order to improve spatial orientation when using 3D models.

The background information on the participants suggests that a digital participation platform is a suitable medium for reaching a broader and more diverse spectrum of the population than is possible in traditional formats. In this context, digital public participation represents an important step towards inclusive participation, a key element of social sustainability.

With regard to the level of detail of 3D models, this study has shown that realistic and detailed 3D models are considered more useful for public participation. However, in order to take different user needs into account, a platform that allows flexible adjustment of the level of detail - from detailed to simplified representations - could be useful.

This study has demonstrated how public participation can be facilitated using BIM model data. The results of this case study suggest that a guided presentation of information, combined with interactive 3D visualization, can significantly enhance citizens' understanding of planned projects. This structured approach appears to be effective in making complex content more accessible and comprehensible, potentially improving the quality of

public participation. However, it is important to acknowledge the relatively small number of participants who actively engaged with the platform beyond merely accessing it. While 593 users visited the site, only 23 individuals participated in the user experience survey. This raises the question of whether some users were deterred by the platform's technological aspects, particularly the 3D models, which could challenge the assumption that BIM-based visualization inherently fosters greater participation. This paradox warrants further investigation.

Future studies should expand the sample size and use detailed models for deeper insights into user experience and acceptance. Comparing 3D visualizations with 2D plans can clarify their advantages in participation, comprehension, and decision-making. Furthermore, integrating citizen feedback into BIM-based planning remains essential.

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References

- [1] Onyimbi, J. R.; Koeva, M.; Flacke, J. (2018) *Public Participation Using 3D Web-Based City Models: Opportunities for E-Participation in Kisumu, Kenya* in: ISPRS International Journal of Geo-Information, 7 (12). <https://doi.org/10.3390/ijgi7120454>
- [2] Skaaland, E.; Pitera, K. (2021) *Investigating the use of visualization to improve public participation in infrastructure projects: how are digital approaches used and what value do they bring?* in: Urban, Planning and Transport Research, 9 (1), pages 171–185. <https://doi.org/10.1080/21650020.2021.1887757>
- [3] vbw-Vereinigung der Bayrischen Wirtschaft e.V. (2018) *Digitales Planen und Bauen-BIM*
- [4] VisB+ Leitfaden BWStiftung_2017_10_25 Fraunhofer IAO_Uni Hohenheim.
- [5] King, Stanley, Conley, Merinda, Latimer, Bill, Ferrari, Drew (1989) *Co-design : a process of design participation* [online]. <https://cir.nii.ac.jp/crid/1130282270751550976> Accessed: 06/12/2024.
- [6] Lane, M. B. (2005) *Public Participation in Planning: an intellectual history* in: Australian Geographer 36 (3), pages 283–299. <https://doi.org/10.1080/00049180500325694>
- [7] Sanford, C.; Rose, J. (2007) *Characterizing eParticipation* in: International Journal of Information Management 27 (6,) pages 406–421. <https://doi.org/10.1016/j.ijinfomgt.2007.08.002>
- [8] Milosz, M.; van Lammeren, R.; Hoogerwerf, T. (2007) *Usability of 3D geo-visualisation for spatial orientation* in: van den Brink, A. [Ed.] *Imaging the future: Geo-visualisation for participatory spatial planning in Europe*. Wageningen Academic Publishers, pages 119–126.
- [9] Borrmann, A. et al. (2021) *Die BIM-Methode im Überblick* in: Borrmann, A. et al. [Ed.] *Building Information Modeling*. Wiesbaden: Springer Fachmedien Wiesbaden, pages 1–34.
- [10] DIN EN ISO 19650-1_ (2019) *Organisation und Digitalisierung von Informationen zu Bauwerken und Ingenieurleistungen einschließlich BIM – Teil 1 Begriffe und Grundsätze*.
- [11] xeokit Web Programming Toolkit for AEC Graphics [online]. <https://xeokit.io/>
- [12] Matthei, J.; Rausch, S.; Klemm-Albert, K. (2024) *BIM-basierte Planfeststellung für Infrastrukturgroßprojekte* in: Bautechnik. <https://doi.org/10.1002/bate.202400016>
- [13] Stadt Düren (2024) *Strukturwandel* [online]. <https://www.dueren.de/wirtschaft-handel/strukturwandel>. Accessed: 18/10/2024.
- [14] Seyser, D.; Zeiller, M. (2018) *Scrollytelling – An Analysis of Visual Storytelling in Online Journalism* in: 2018 22nd International Conference Information Visualisation. Fisciano, Italy. IEEE, pages 401–406.
- [15] Leitner, M. (2018) *Digitale Bürgerbeteiligung: Chance und Herausforderung* in: Leitner, M. [Ed.] *Digitale Bürgerbeteiligung*. Wiesbaden: Springer Fachmedien Wiesbaden, pages 1–10.
- [16] Morozov, E. (2009) *Foreign Policy: Brave New World Of Slacktivism* [online]. <https://www.npr.org/2009/05/19/104302141/foreign-policy-brave-new-world-of-slacktivism> Accessed: 10/11/2024.
- [17] Klages, H.; Vetter, A. (2013) *Bürgerbeteiligung auf kommunaler Ebene-Perspektiven für eine systematische und verstetigte Gestaltung*. Baden-Baden: Nomos Verlagsgesellschaft mbH&Co.KG.
- [18] Fernández Guzmán Grassi, E.; Portos, M.; Felicetti, A. (2024) *Young People's Attitudes towards Democracy and Political Participation: Evidence from a Cross-European Study* in: Government and Opposition 59 (2), pages 582–604. <https://doi.org/10.1017/gov.2023.16>
- [19] Partarakis, N.; Zabulis, X. (2024) *A Review of Immersive Technologies, Knowledge Representation, and AI for Human-Centered Digital Experiences* in: Electronics 13 (2), <https://doi.org/10.3390/electronics13020269>